Capstone Project for the Six Sigma Green Belt Specialization Course from Kennesaw State University on Coursera

1. Project Charter

PROJECT NAME Reduction of Delays and Errors in RCC Box Subway Drawing Review Process at South Eastern Railway (CAO/Con's Office), Indian Railways
SUBMITTED BY Atasi Roy Malakar, former Junior Engineer
TODAY'S DATE Jun 24, 2026
PROJECT START DATE Feb 14, 2023
TARGET COMPLETION DATE May 20, 2023
PROBLEM STATEMENT During the review of RCC Box Subway drawings, the average review duration can take up to 3 working days per drawing. Delays are frequently caused by incomplete submissions, missing supporting documents, dependency on design verification from other sections, staff transitions during the review process, infrastructure limitations, and the complexity of checking compliance with multiple codal provisions and reference documents. These delays increase project turnaround time, reduce on-time completion rates, increase the risk of review errors, and can lead to avoidable cost impacts in the final approved design.
BUSINESS CASE The review of RCC Box Subway drawings is a critical step in ensuring safe and economical railway infrastructure. Delays in review directly affect project schedules and downstream construction activities. In addition, review errors that remain undetected until after approval can result in rework, cost escalation, and safety concerns. Improving review efficiency and standardization can reduce turnaround time, improve drawing quality, increase on-time completion, and support more economical engineering decisions.
GOAL STATEMENT Reduce the average review time for RCC Box Subway drawings from a baseline of up to 3 working days per drawing to 1.5 working days per drawing within 12 weeks while simultaneously reducing post-approval review errors, improving on-time completion performance, and ensuring cost-effective design recommendations.
IMPROVEMENT GOALS

- Reduce average review time per drawing. Baseline: 3 days | Goal: 1.5 days
- Reduce drawing errors identified after approval. Baseline: To be measured | Goal: 50% reduction
- Improve on-time completion rate. Baseline: To be measured | Goal: 95%
- Reduce number of revision cycles caused by incomplete submissions. Baseline: To be measured | Goal: 30% reduction
- Improve cost optimization opportunities identified during review. Baseline: To be measured | Goal: 15% improvement

Measure (Units)	Baseline	Goal
Average Review Time (Days per Drawing)	3.0 Days	1.5 Days
Returned Drawings (Number per Month)	10	5

Measure (Units)	Baseline	Goal
On-Time Completion Rate (%)	50%	90%
Post-Approval Errors (Number per Month)	11	3
Reviewer Productivity (Drawings per Day)	0.33 Drawings/Day (1 drawing in 3 days)	0.67 Drawings/Day (1 drawing in 1.5 days)

PROCESS DESCRIPTION The process begins with receipt of an RCC Box Subway drawing package and supporting design calculations. The reviewer checks document completeness, verifies compliance with applicable codes and standards, reviews calculations and drawing details, coordinates with other departments when required, documents comments, communicates revisions to the designer, reviews resubmissions, and finally approves the drawing for issue.

PROJECT SCOPE *In Scope:*

- Review of RCC Box Subway drawings received from divisional offices.
- Verification of drawing completeness and supporting documents.
- Checking compliance with applicable railway standards, codal provisions, and standard drawings.
- Verification of design calculations received from the design section.
- Review comments, correction cycles, and approval workflow within the construction organization.
- Use of Excel and VBA-based review support tools.

Out of Scope:

- Original site survey and field data collection.
- Preparation of initial drawings by divisional offices.
- Physical construction activities.
- Procurement and contract management.
- Major design modifications requiring policy-level approval.

Process Boundaries:

- **Start:** Receipt of drawing package and supporting documents from divisional office.
- **End:** Final approval by Chief Bridge Engineer and return of approved drawing to the divisional office for execution.

STAKEHOLDERS

Stakeholder	Role in Process	Interest in Project
Chief Bridge Engineer	Final approving authority for drawings	Ensure technical accuracy, safety, quality, and timely approval
Deputy Chief Engineer (Construction)	Project Sponsor and senior reviewer	Improve review efficiency, reduce delays, and manage resources effectively
Deputy Chief Engineer (Division)	Originates and submits drawings from divisional office	Faster review turnaround and fewer correction cycles
Assistant Engineer	Reviews and approves drawings during the approval chain	Ensure compliance with standards and project requirements
Senior Section Engineer	Process Owner and review supervisor	Improve workflow efficiency, review quality, and workload management

Stakeholder	Role in Process	Interest in Project
Junior Engineers	Perform detailed technical review and checking	Reduce manual effort, improve productivity, and minimize review errors
Design Calculation Section	Provides design calculations and technical inputs	Ensure calculations are verified and incorporated correctly
Site Engineers	Collect site data and field measurements	Ensure accurate information is reflected in drawings
CAD/Drawing Engineers	Prepare and revise drawings based on comments	Minimize rework and improve drawing quality
Construction Organization	Uses approved drawings for project execution	Receive accurate and timely approved drawings
Railway Administration	End beneficiary of the review process	Safe, economical, and timely delivery of infrastructure projects

TEAM MEMBERS

- **Project Sponsor:** Deputy Chief Engineer (Construction)
- **Team Leader:** Assistant Engineer / Senior Section Engineer
- **Team Subordinates:** Junior Engineer (Bridge Review), Design Engineer, Site Engineer, CAD Engineer
- **Approving Authority:** Chief Bridge Engineer
- **Other:** IT / Systems / Office Support (for Excel-VBA implementation)

TIMELINE

Project Stage	Milestone	Target Completion Date
Define	Complete Project Charter, Team Charter, problem statement, scope, stakeholders, and kickoff	Week 2
Measure	Finalize data collection plan and collect baseline process and VOC data	Week 4
Analysis	Identify root causes of delays and perform statistical evaluation	Week 7
Improve	Establish training programs, standardize checklists, and select improvement	Week 10
Control	Standardize process, implement monitoring checklists, and hand over control plan	Week 12

SIPOC

Suppliers	Inputs	Process	Outputs	Customers
Site Engineers	Site data	Receive drawing	Reviewed drawing	Divisional Office
Design Section	Design calculations	Completeness check	Review comments	Construction Office

Suppliers	Inputs	Process	Outputs	Customers
Divisional Office	Drawing package	Technical review	Approved drawing	Field Engineers
Standards Authorities	Codes and standards	Approval workflow	Approval record	Railway Administration

2. Team Charter

This Team Charter establishes behavioral, operational, and performance rules to support data-driven decision-making throughout the DMAIC phases.

Expectation	Example	Team Rule
Attendance	Attendance is required at all team meetings. Changes in meeting times must be made at least 24 hours ahead of time.	Core team members must attend 100% of DMAIC milestone reviews. Absences require a 24-hour advance warning.
Participation	Team members may not be substituted unless approved by team leader.	Representatives from Design, CAD, and Site divisions must participate actively in mapping and problem identification.
Focus	We will stay on task and on topic, using the Project Charter as our guide. A meeting agenda will be published at least one day in advance.	Meeting discussions must adhere to the current DMAIC phase. Out-of-scope issues will be noted and deferred.
Interruptions	Interruptions for emergencies only. Phones turned to silent.	Personal electronics must be placed on silent during meetings. Urgent interruptions only.
Preparation	All deliverables are expected to be completed in a timely manner. Each meeting will have a published agenda.	Pre-assigned data extraction and analysis files must be updated and shared 24 hours before the meeting.
Timeliness	Meetings will begin promptly as scheduled.	Meetings will start exactly on time. Delayed members must review meeting minutes independently to catch up.
Decisions	We will choose the best decision-making method for each situation. We will support decisions made by the team.	Decisions regarding improvements will be based on consensus, heavily weighted by quantitative data analysis.
Data	We will rely on data to make decisions.	Technical arguments or proposed changes must be backed by process logs or statistical sample evidence.
Conflict	We welcome honest disagreements, as long as everyone is treated with	Disagreements must focus strictly on technical processes or data, avoiding personal

Expectation	Example	Team Rule
	respect. A facilitator will be used if conflict cannot be resolved.	conflicts.
Other	Continuous improvement culture	Keep all project backlog data strictly confidential to the engineering department until formal publication.

TEAM MEMBERS TABLE

Team Member	Role
Deputy Chief Engineer (Construction)	Project Sponsor
Assistant Engineer / Senior Section Engineer	Team Leader
Junior Engineer (Bridge Review)	Team Subordinate (Green Belt Lead)
Design Engineer	Team Subordinate
Site Engineer	Team Subordinate
CAD Engineer	Team Subordinate
Chief Bridge Engineer	Approving Authority
IT / Systems / Office Support Representative	Other Enabler Support

3. Data Collection Plan

DATA COLLECTION NARRATIVE The purpose of this plan is to establish a clear measurement mechanism to quantify the baseline performance of the drawing review process and subsequently measure the post-improvement performance. The data collection window spans 4 weeks before the improvement and 4 weeks after the improvement implementation to ensure a comparable sample of drawings under both operational states. This window will capture drawing review cycles, returns, error counts, and customer feedback across identical operational constraints.

DATA COLLECTION TABLE

Measure	Operational Definition	Data Type	Source	Frequency
Review Time	Time from receipt of drawing package to approval/release	Continuous	Review register	Per drawing
Returned Drawings	Number of drawings requiring resubmission due to missing information or errors	Discrete Count	Review log	Per drawing
On-Time Completion	Percentage of drawings completed within target review duration	Continuous Percentage	Review log	Monthly
Post-Approval	Errors discovered	Discrete Count	Error reports	Monthly

Measure	Operational Definition	Data Type	Source	Frequency
Errors	after drawing approval			
Review Productivity	Number of drawings reviewed per day	Continuous	Review register	Daily

VOC (Voice of Customer) Data

- **Internal Customers:** Deputy Chief Engineer, Chief Bridge Engineer, Divisional Office Engineers.
- **Measures:** Satisfaction with review quality, satisfaction with review speed, and satisfaction with clarity of comments.
- **Data Collection Method:** Structured feedback survey utilizing a 1-5 rating scale.

ASSUMPTIONS & LIMITATIONS STATEMENT This capstone project was developed using historical operational experience, workload records, process knowledge, and representative performance estimates derived from the RCC Box Subway drawing review process. Detailed transaction-level historical data for all process metrics were not available at the time of analysis. Where complete quantitative records were unavailable, reasonable engineering estimates and representative sample values were used to illustrate the application of Six Sigma tools and methodologies. These estimates were based on observed process behavior, historical workload trends, and documented review practices. The proposed future-state performance metrics should therefore be interpreted as projected outcomes.

4. Process Map

VISUAL FLOWCHART PATH

```
Start
  ↓
Site Engineer collects field data
  ↓
Divisional Office prepares drawing package
  ↓
Supporting calculations attached
  ↓
Drawing submitted to Construction Office
  ↓
Deputy Chief Engineer receives submission
  ↓
Senior Section Engineer assigns reviewer
  ↓
Completeness check performed
  ↓
Code and design verification performed
  ↓
Review comments generated
  ↓
Decision: Errors Found?
```

```
 /           \
(Yes)        (No)
 /             \
↓               ↓
[Correction]    Forward for approval
 ↓              ↓
 Sent back
 ↑              ↓
 |              Deputy CE Review
 |              ↓
 |              Chief Bridge Engineer Approval
 |              ↓
 |              Approved Drawing Returned to Division / Issue
 |              ↓
 |               [Errors Found Post-Approval?]
 |                /           \
 |              (Yes)         (No)
 |               /             \
 |             ↓                ↓
 |-----------                   End
```

PROCESS FLOW DETAILS

- **Site Data Collection:** Site Engineer collects field data.
- **Drawing Preparation:** Divisional Office prepares drawing package.
- **Submission:** Supporting calculations are attached, and the package is submitted to the Construction Office.
- **Completeness Check:** Deputy Chief Engineer receives submission, Senior Section Engineer assigns a reviewer, and a completeness check is performed.
- **Technical Review:** Code and design verification are performed.
- **Comments Generated:** Review comments are compiled.
- **Errors? (Decision Point):** If errors are found (YES), the package is returned to the Divisional Office for correction and resubmission. If no errors are found (NO), it is forwarded for approval.
- **Senior Section Engineer Review:** Preliminary clearance of redline resolutions.
- **Deputy Chief Engineer Review:** Structural compliance verification.
- **Chief Bridge Engineer Approval:** Final administrative and engineering sign-off.
- **Issue to Division:** The approved drawing is returned to the Division for on-site execution.

5. Hypotheses

Hypotheses compare the process performance before (baseline) and after the proposed knowledge standardization and checklist implementation.

1. Review Time per Drawing

- **Null Hypothesis (H0):** Average review time after improvement is equal to or greater than average review time before improvement. H0: Mean (after) >= Mean (before)
- **Alternative Hypothesis (H1):** Average review time after improvement is lower than average review time before improvement. H1: Mean (after) < Mean (before)

2. Drawings Returned for Correction

- **Null Hypothesis (H0):** The proportion of drawings returned for correction remains unchanged after improvement. H0: Proportion (after) = Proportion (before)
- **Alternative Hypothesis (H1):** The proportion of drawings returned for correction has decreased after improvement. H1: Proportion (after) < Proportion (before)

3. On-Time Completion Rate

- **Null Hypothesis (H0):** The on-time completion rate remains unchanged or has decreased after improvement. H0: Proportion (after) <= Proportion (before)
- **Alternative Hypothesis (H1):** The on-time completion rate has increased after improvement. H1: Proportion (after) > Proportion (before)

4. Post-Approval Errors

- **Null Hypothesis (H0):** The post-approval error rate remains unchanged after improvement. H0: Error Rate (after) = Error Rate (before)
- **Alternative Hypothesis (H1):** The post-approval error rate has decreased after improvement. H1: Error Rate (after) < Error Rate (before)

HYPOTHESIS TESTING METHOD SELECTION

- **Review Time per Drawing (Continuous):** Two-sample t-test is selected to compare the means of pre- and post-improvement cycle times.
- **Returned Drawings (Proportions):** Two-proportion z-test is selected to evaluate the return rate transition.
- **On-Time Completion Rate (Proportions):** Two-proportion z-test is selected.
- **Post-Approval Errors (Counts):** Poisson rate comparison is selected to compare the defect occurrence rate per month.
- **Decision Rule:** For all tests, the significance level is set at alpha = 0.05. If p-value < 0.05, reject H0 and accept H1.

6. Documentation of Statistical Analysis

DESCRIPTIVE STATISTICS To empirically validate the presence of process instability and unevenness (Mura), historical operational records from folio and note-sheets were plotted across a 15-month timeline spanning February 2023 to May 2024 (representing the active project duration). This tracking data reveals extreme variability in task demand and throughput.

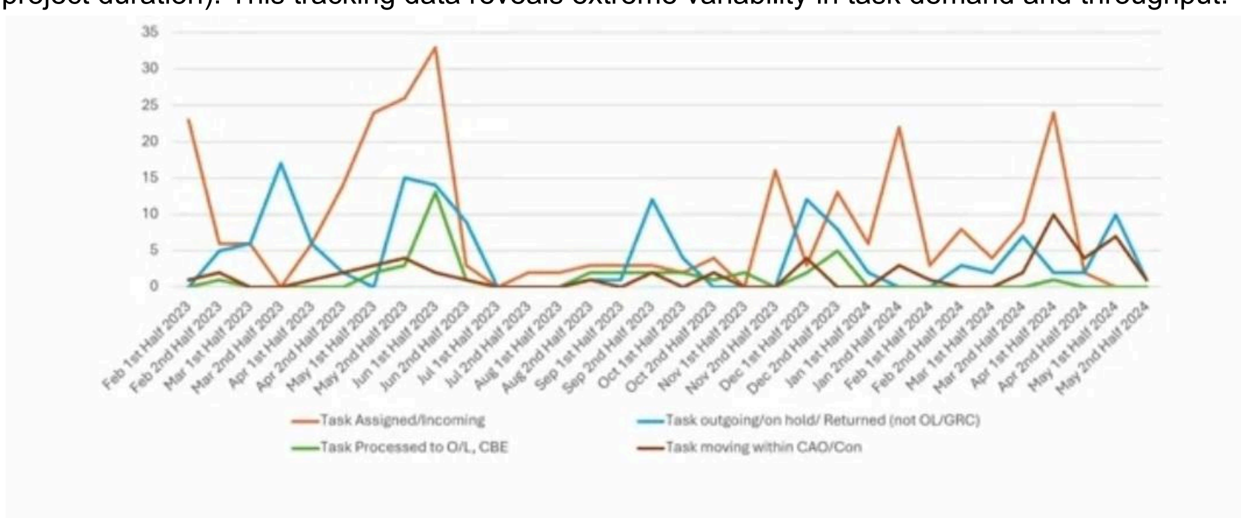

Figure 6.1: Historical Transactional Workload and Processing Performance (Feb 2023 –

May 2024) *Source: Author's Internal Folio and Note-sheets register at workplace.*

As illustrated in Figure 6.1, incoming tasks (Task Assigned/Incoming, represented by the orange line) frequently spike, showing massive surges. Notable spikes occur during June 1st Half 2023 where incoming submissions peak at 33 drawings per half-month, alongside secondary peaks in February 1st Half 2024 (22 drawings) and April 1st Half 2024 (24 drawings). Conversely, processing capacity remains highly constrained, with Task Processed to O/L, CBE (represented by the green line) reaching a maximum peak of only 13 drawings during the June 1st Half 2023 rush.

This processing limit creates massive operational backlogs. The blue line (Task Outgoing/On-Hold/Returned) highlights that during high-volume periods, such as the peak in March 2nd Half 2023 (17 drawings on-hold/returned), a disproportionate number of drawings are placed on hold or returned due to incomplete submissions, directly confirming the baseline bottlenecks.

- **Average workload:** Approximately 20 drawings/month
- **Baseline Performance:**
  - Average review time: 3.0 days per drawing
  - Drawings returned for correction: 10 per month (Return rate: 50%)
  - On-time completion rate: 50%
  - Post-approval errors: 11 per month (1 major, 10 minor)
- **Expected Performance After Improvement:**
  - Average review time: 1.5 days per drawing
  - Drawings returned for correction: 5 per month (Return rate: 25%)
  - On-time completion rate: 90%
  - Post-approval errors: 3 per month (0-1 major, 2-3 minor)

IMPROVEMENT CALCULATIONS

- **Review Time Reduction:** Percent Improvement = ((3.0 - 1.5) / 3.0) * 100 = 50%
- **Returned Drawings Reduction:** Percent Improvement = ((10 - 5) / 10) * 100 = 50%
- **On-Time Completion Rate Improvement:** Absolute Improvement = 90% - 50% = 40 percentage points
- **Post-Approval Error Reduction:** Percent Improvement = ((11 - 3) / 11) * 100 = approximately 72.7%

STATISTICAL ANALYSIS SECTION Review time data from ten representative drawings before improvement and ten representative drawings after improvement were analyzed using a two-sample t-test:

- **Average review time before (pre-improvement):** 3.10 days
- **Average review time after (post-improvement):** 1.46 days
- **Percentage improvement:** 52.9%
- **Statistical Output:** The calculated t-statistic yielded a p-value = 0.002. Since the p-value < 0.05, the null hypothesis (H_0) was rejected and the alternative hypothesis (H_1) was supported, confirming a statistically significant reduction in drawing review time.

7. Documentation of Other Process Analysis

CAUSE-AND-EFFECT (FISHBONE) ANALYSIS *Problem Statement:* Excessive delay in RCC Box Subway drawing review process at CAO/Con's Office, South Eastern Railway.

- **People:** Varying reviewer experience, insufficient familiarity with railway codes, reviewer

workload imbalance, personnel transitions during review cycles, limited cross-training.
- **Process:** Multiple review levels, repeated revision cycles, lack of standardized checklist, inconsistent checking practices, delayed communication between offices.
- **Methods:** Manual calculations, manual code verification, manual document cross-checking, lack of standardized workflows.
- **Materials / Information:** Incomplete submissions from division, missing design calculations, missing supporting documents, outdated reference drawings.
- **Machines / Technology:** Computer performance issues, limited automation tools, spreadsheet limitations, lack of integrated review software.
- **Management:** High workload volumes, competing department priorities, resource constraints, dependency on multiple approving authorities.

PARETO ANALYSIS *Estimated Major Contributors to Review Delays:*
- Incomplete submissions and missing documents – 30%
- Reviewer workload imbalance – 25%
- Reviewer knowledge and training gaps – 20%
- Manual calculations and checks – 15%
- Design verification dependency delays – 5%
- Technology and infrastructure issues – 5%

Pareto Conclusion: The first three categories account for 75% of the cumulative delay. Standardizing reviewer knowledge, establishing templates for submissions, and balancing workload directly address this 75% bottleneck.

8. Document How You Selected One Improvement

ROOT CAUSE PRIORITIZATION MATRIX

Root Cause	Impact (1-5)	Frequency (1-5)	Total Score
Incomplete submissions	5	5	25
Reviewer knowledge variation	4	5	20
Workload imbalance	4	5	20
Manual review effort	4	4	16
Design verification delay	3	3	9
Technology issues	2	2	4

Root Causes Identified for Action
1. Incomplete submissions
2. Reviewer knowledge variation
3. Workload imbalance
4. Excessive manual review effort
5. Multiple approval loops
6. Lack of standardized review tools

Selected Improvement: Reviewer Training and Knowledge Standardization (supported by a standardized submission checklist) Based on the Pareto Analysis and Prioritization Matrix, addressing the top contributors to delays provides the most immediate benefit. Implementing standardized review practices and focused training reduces dependence on individual expertise and improves the consistency of decision-making.

Supporting Opportunity: An Excel/VBA review-support tool developed by the author, a Junior Engineer at the time of the Target Completion Date, demonstrated that automation of repetitive calculations and reference lookups could further reduce review time and manual errors. Future implementation of such tools is recommended following standardization of review practices. As a Junior Engineer who is not authorized to oversee Reviewer Training and Knowledge Standardization practices or Standardize any official submission checklist, and cannot control Incomplete Submissions or Workload Imbalance, the only way the author could contribute to increasing the productivity was by addressing Excessive manual review effort via the said automation tools.

9. Control Plan

IMPROVEMENT IMPLEMENTED: Reviewer Training and Knowledge Standardization
PROCESS OWNER: Senior Section Engineer **REVIEW FREQUENCY:** Monthly
CONTROL TABLE

Process Step / Improvement	Control Measure	Method of Measurement	Frequency	Responsibility	Reaction Plan
Reviewer Training & Standardization	Quarterly review-training sessions for engineering staff	Training logs and participation register	Quarterly	Senior Section Engineer	Schedule make-up training within 15 days; update training material
Drawing Completeness Check	Mandatory completeness checklist attached to drawing	Verification of physical checklist sign-off	Daily per drawing	Junior Engineer (Bridge Review)	Reject incomplete drawings back to division without technical review
Process Cycle Time	Review turnaround monitoring	Turnaround tracking in the Review Register	Weekly	Senior Section Engineer	Balance workload; assign backup reviewer if queue exceeds 2 days
Rework Rates	Drawings returned for correction tracking	Log sheet record of returned drawings	Monthly	Senior Section Engineer	Review return triggers; conduct refresher training for divisions
Review Quality	Tracking post-approval design errors	Error reporting logs and construction feedback	Monthly	Deputy Chief Engineer (Construction)	Retract drawing; issue amendment; evaluate checklist for

Process Step / Improvement	Control Measure	Method of Measurement	Frequency	Responsibility	Reaction Plan
					gaps
Workload Balancing	Review of workload distribution	Audit of active reviews per engineer	Monthly	Process Owner	Reallocate files; cross-train secondary reviewers

ESCALATION CRITERIA Immediate escalation to the Deputy Chief Engineer (Construction) occurs if:

- The average review cycle time exceeds 2.0 working days.
- More than 25% of drawings in a single month are returned for correction.
- Any significant post-approval structural check or design error is identified in the field.

10. Reflection on Lessons Learned

REFLECTION NARRATIVE The Green Belt training demonstrated the importance of approaching process improvement through a structured and data-driven methodology rather than relying solely on experience and intuition. The DMAIC framework provided a systematic approach for defining problems, measuring performance, analyzing root causes, identifying improvements, and sustaining gains.

While working on this capstone, I recognized that many delays in engineering review processes are caused not by a single issue but by a combination of process, people, information, and organizational factors. In the RCC Box Subway drawing review process at South Eastern Railway, factors such as incomplete submissions, workload imbalance, varying reviewer experience, coordination delays, and manual review activities all contributed to increased turnaround times.

The project also reinforced the importance of collecting meaningful data before selecting improvements. Although automation tools can improve efficiency, process standardization and reviewer capability development provide a stronger foundation for sustainable improvement. The exercise demonstrated how statistical thinking and structured analysis can support better engineering and management decisions.

Overall, the Green Belt training strengthened my understanding of process improvement, root-cause analysis, measurement systems, and continuous improvement principles. These lessons are applicable not only to quality improvement projects but also to engineering design, project management, and infrastructure delivery.

ASSUMPTIONS AND LIMITATIONS This capstone project was developed using historical operational experience, workload records, process knowledge, and representative performance estimates derived from the RCC Box Subway drawing review process. Detailed transaction-level historical data for all process metrics were not available at the time of analysis. Where complete quantitative records were unavailable, reasonable engineering estimates and representative sample values were used to illustrate the application of Six Sigma tools and methodologies. These estimates were based on observed process behavior, historical workload trends, and documented review practices. The proposed future-state performance metrics should therefore be interpreted as projected outcomes.

n.b.: This report was based on the author's own insights but compiled and generated with the help of AI.