



Industrial Research Presentation

*Design, Development and Evaluation of
an Automated CAD Quality Assurance
System for Civil Engineering Workflows*

Topics



Background and
Rationale



Literature Review
Summary



Aim and
Objectives



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Methodology



Technical
Approach and
System Design



Project Planning
and Resources



Impact and
Limitations

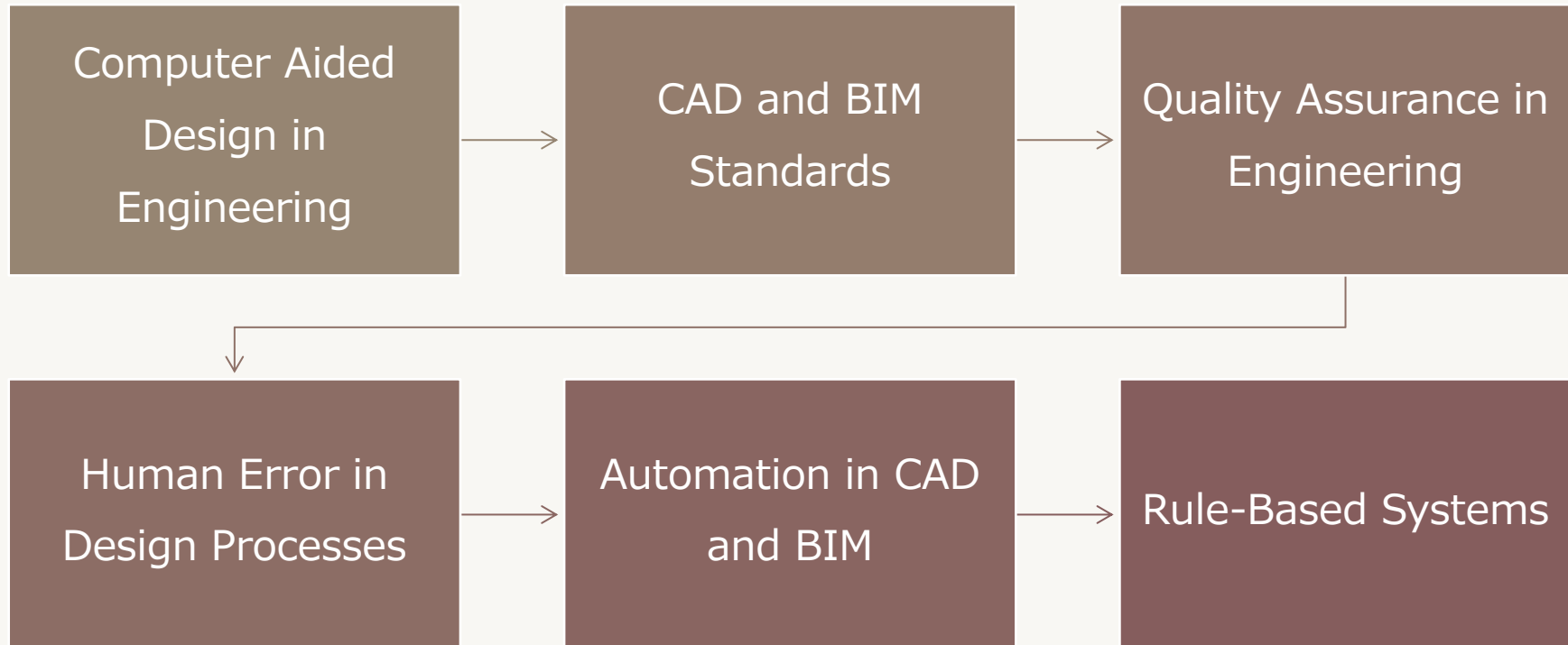


Further
Developments

Background and Rationale

- Engineering drawings and models are essential for communicating detailed designs across the industry.
 - Manual CAD QA checks are slow, inconsistent, and prone to human error, causing delays in engineering workflows and project delivery.
 - Engineering organisations struggle to maintain drafting standard compliance under manual QA processes.
 - Existing QA tools automate some checks but do not fully validate engineering rules or industry standards.
 - Several studies explore CAD standards and BIM validation, but limited research exists on fully automated QA for engineering drawings and models.
 - Current solutions focus mainly on geometry or metadata rather than rule-based validation checks or engineering constraints.
 - As a result, organisations lack automated systems that can reliably detect quality issues without manual input.
 - This project addresses these problems by exploring automated, rule-based QA tools to improve the quality and consistency of engineering designs.
 - The identified gap informs the research question, prompting an investigation into whether automated systems can improve consistency, reliability, and efficiency compared with manual practices.
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Literature Review Topics



Literature Review Summary

- Increasing complexity of engineering deliverables require faster development cycles, reliable and robust digital validation techniques
- Common issues such as poor design quality, inefficiency and human error can lead to an increase in time, costs and resources, potential rework and extended delivery times
- Inconsistent application of CAD/BIM standards to work packages
- Slow and error-prone manual checking processes
- Existing QA procedures are difficult to scale due to them being heavily reliant on human input and manual updates
- Poorly suited to multidisciplinary projects that involve various tools and data formats
- Automation methods targeted at CAD quality assurance and compliance improve quality
- Automated rule-based systems improve the consistency of standards, reduce human error and support creating scalable QA tools
- ***Research Gap: Rule based systems can support teams in improving consistency and compliance with automated standards and quality assurance checks, allowing the team to produce reliable, efficient and standardized CAD drawings and models***

Aim and Objectives

The project aims to design, develop, and evaluate an offline, rule-based CAD quality-assurance tool capable of automatically validating civil engineering drawings against organisational drafting standards.

Objectives:

- Investigate current CAD QA processes used within civil engineering
- Review academic and industrial research on engineering QA, CAD standards and workflow automation
- Design a rule-based validation architecture for CAD drawing and model assessment
- Develop a python prototype to analyses DXF files
- Implement validation rules for common drafting standards
- Generate automated QA reports for users
- Evaluate performance compared manual processes



Minimal Viable Project and Success Criteria

Minimal Viable Project

- To develop a system that demonstrates the CAD quality assurance tool's core values.
- Creating a working prototype which can load CAD files, validation checks, and produce a outputs that highlights detected QA issues to the user.
- Ensure that the project's aim remains achievable within the project timeline with time and resources available
- Providing a foundation for the QA tool
- Offline Python-based CAD QA tool
- DXF parsing using ezdxf
- Core rule-based validation (text height, layers, line types)
- Pass/fail reporting
- Simple UI for file selection and rule execution
- Exportable QA report

Success Criteria

- Track project progress and support evaluation by assessing
- Measurable indicators for the developer to focus on the technical performance, functionality, reliability and usability of the QA tool
- Tool correctly identifies rule violations
- Processing time significantly faster than manual QA
- Consistent results across repeated runs
- Positive feedback from technicians
- Clear, readable QA report
- Prototype stable enough for evaluation testing

The success criteria focus on functional accuracy, standard compliance, usability, technical performance and user feedback and the project will be deemed successful once the specified targets have been achieved.

Research Methodology



PHILOSOPHES

- Positivism, pragmatism and interpretivism will ensure that technical issues within current engineering workflows are carefully considered.
- These philosophies support reviewing suggestions from user feedback sessions during prototype development.
- They help identify repetitive QA errors and understand the impacts on the user.
- They ensure suitable improvements can be made to support validation checks and compliance of engineering models.

STRATEGIES

- Strategies such as software development, survey research and experimentation will be adopted on this project to support the implementation of the rule-based CAD QA tool.
- Collecting feedback from various technicians and engineers will support understanding the current challenges with existing workflows, standard implementation and compliance.
- Feedback will provide examples of design considerations to review during testing to assess the accuracy, consistency and performance of the tool.

METHODS

- Both qualitative and quantitative methods will be employed to collect data before the prototype development stages.
- This approach ensures sufficient detail is available to support project delivery through feedback, evaluations and testing of existing methods.
- Qualitative and quantitative data collection techniques will be utilised to assess existing workflows and inform prototype testing.

Research Methods

QUALITATIVE METHODS

- Interviews
- Observations of current working practices and QA procedures
- Technical Document Analysis of BEPs and CAD Standards
- User Experience Feedback
- Expert Heuristic Evaluation

QUANTITATIVE METHODS

- Surveys
- Error Frequency Analysis System
- Performance Metrics
- Experimental Testing of Validation Rules



Intended User Group

- User group: highway engineers and technicians who produce drawings and carry out manual QA checks.
- Feedback from intended users will guide validation rules and system design to align with quality check requirements.
- After prototype approval by the highways team, the tool may be shared with wider teams to support CAD standards and QA compliance across the organisation.
- Wider rollout will provide additional user feedback to inform future development, including discipline-specific validation rules.

Technical Approach and System Design



STORYBOARD



ARCHITECTURE
DIAGRAM

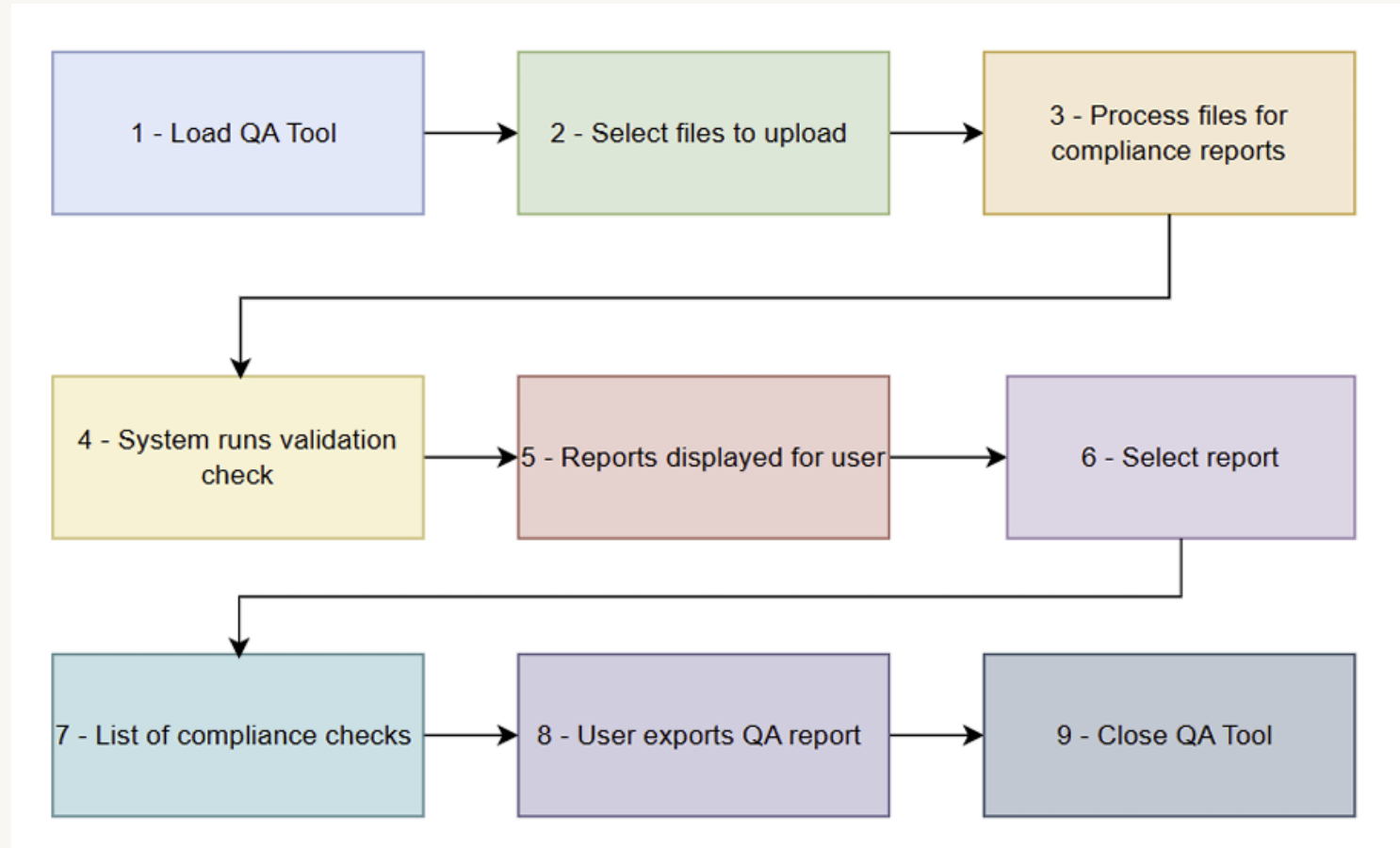


RULE LOGIC
FLOWCHARTS



USER INTERFACE
DESIGN

- The project's technical approach is to build a working prototype that automatically checks engineering drawings and models using predefined validation rules.
- The system will manage file input, rule processing, validation checks and output generation.
- The design aims to ensure the prototype is easy to maintain, expand and meets minimum project requirements.
- The system design process includes creating storyboards, architecture diagrams, validation rule flowcharts and user interface designs.
- These design artefacts visually represent how the QA tool works and show how data flows through the system as users interact with it.



UX Storyboard Flowchart

1. Launch CAD QA Tool

CAD QA Tool

Add Files Remove Files

File	Status	Output	Results

Process Files

2. Select files for compliance check

CAD QA Tool

Add Files Remove Files

File	Status	Output	Results

Process Files

File Name	Status	Date	Type	Size
UWSTD-IBR-XXXX-XX-DR-000001	✓	dd/mm/yyyy	dxf	5 MB
UWSTD-IBR-XXXX-XX-DR-000002	✓	dd/mm/yyyy	dxf	5 MB
UWSTD-IBR-XXXX-XX-DR-000003	✓	dd/mm/yyyy	dxf	5 MB

OK

3. Process files for compliance report

CAD QA Tool

Add Files Remove Files

File	Status	Output	Results
UWSTD-IBR-XXXX-XX-DR-000001			
UWSTD-IBR-XXXX-XX-DR-000002			
UWSTD-IBR-XXXX-XX-DR-000003			

Process Files

UX Storyboard

- The UX storyboard shows the typical workflow a technician or engineer follows when using the CAD QA tool.
- It maps the sequence of user actions: loading a drawing or model, running validation rules, reviewing compliance issues, and applying corrective changes.
- The storyboard demonstrates how the system supports QA compliance and ensures the prototype aligns with real user workflows.
- It highlights where clear feedback and simple navigation are essential for effective user adoption.

4. System runs validation checks

CAD QA Tool

Add Files Remove Files

File	Status	Output	Results
UWSTD-IBR-XXXX-XX-DR-000001	Pending	UWSTD-IBR-XXXX-XX-DR-000001.pdf	
UWSTD-IBR-XXXX-XX-DR-000002	Pending	UWSTD-IBR-XXXX-XX-DR-000002.pdf	
UWSTD-IBR-XXXX-XX-DR-000003	Pending	UWSTD-IBR-XXXX-XX-DR-000003.pdf	

Process Files

5. Report Displayed for User

CAD QA Tool

Add Files Remove Files

File	Status	Output	Results
UWSTD-IBR-XXXX-XX-DR-000001	Complete	UWSTD-IBR-XXXX-XX-DR-000001.pdf	Pass
UWSTD-IBR-XXXX-XX-DR-000002	Complete	UWSTD-IBR-XXXX-XX-DR-000002.pdf	Pass
UWSTD-IBR-XXXX-XX-DR-000003	Complete	UWSTD-IBR-XXXX-XX-DR-000003.pdf	Fail

Process Files

6. Select Report

CAD QA Tool

Add Files Remove Files

File	Status	Output	Results
UWSTD-IBR-XXXX-XX-DR-000001	Complete	UWSTD-IBR-XXXX-XX-DR-000001.pdf	Pass
UWSTD-IBR-XXXX-XX-DR-000002	Complete	UWSTD-IBR-XXXX-XX-DR-000002.pdf	Pass
UWSTD-IBR-XXXX-XX-DR-000003	Complete	UWSTD-IBR-XXXX-XX-DR-000003.pdf	Fail

Process Files

7. List of compliance checks

QA Report

UWSTD-IBR-XXXX-XX-DR-000001

QA Rules	Status
Layer Naming Convention	Pass
Text Height	Fail
Text Style	Pass
Line Types	Fail
No Elements on Layer 0	Warning
Layer not in library list	Warning

Exit Next Report Previous Report Export Report

8. User exports QA report

QA Report

UWSTD-IBR-XXXX-XX-DR-000001

QA Rules	Status
Layer Naming Convention	Pass
Text Height	Fail
Text Style	Pass
Line Types	Fail
No Elements on Layer 0	Warning
Layer not in library list	Warning

Exit Next Report Previous Report Export Report

9. Export downloaded

QA Report

UWSTD-IBR-XXXX-XX-DR-000001

QA Rules	Status
Layer Naming Convention	Pass
Text Height	Fail
Text Style	Pass
Line Types	Fail
No Elements on Layer 0	Warning
Layer not in library list	Warning

UWSTD-IBR-XXXX-XX-DR-000001.pdf Downloaded

Exit Next Report Previous Report Export Report

10. Exit and Close Application

QA Report

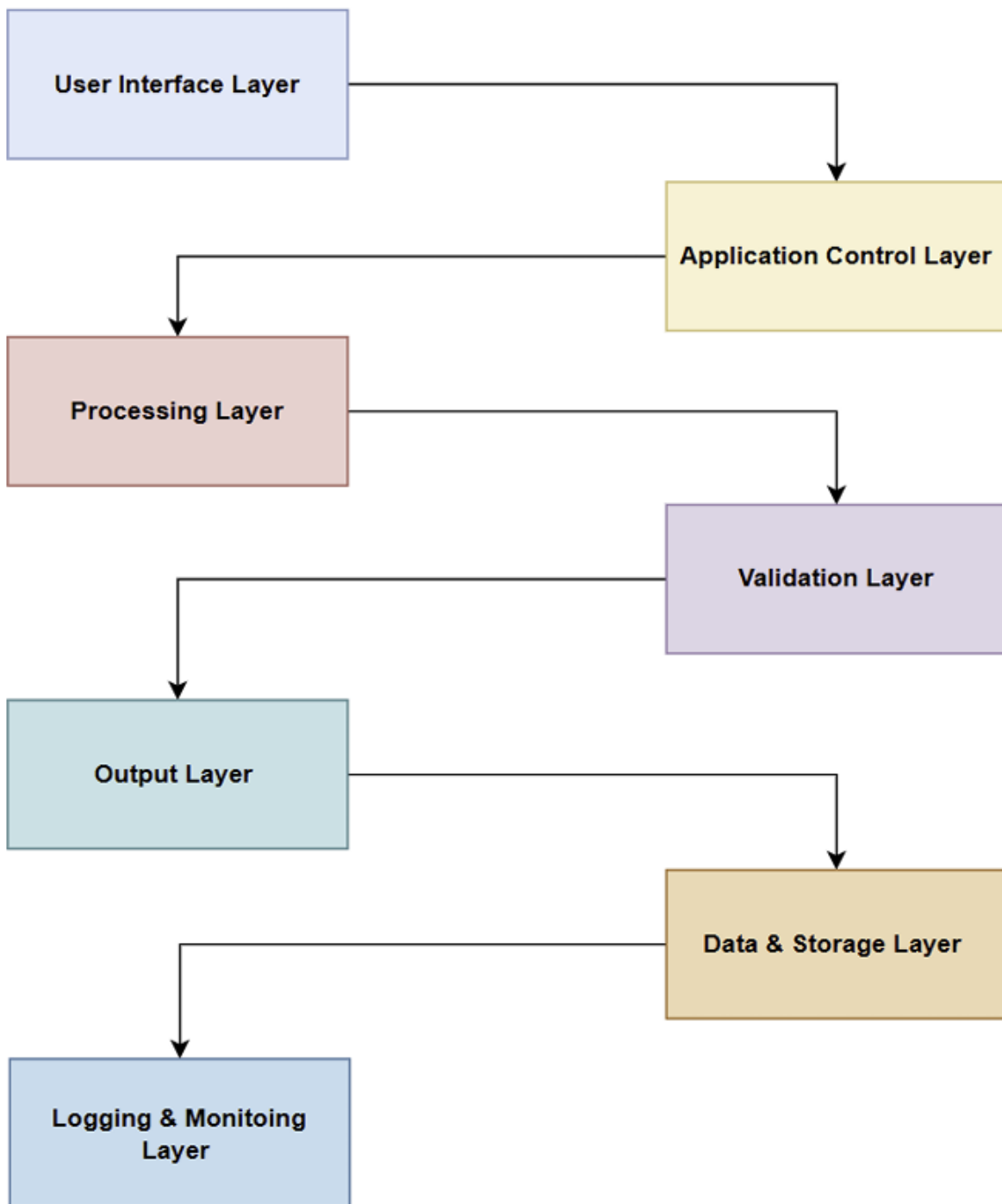
UWSTD-IBR-XXXX-XX-DR-000001

QA Rules	Status
Layer Naming Convention	Pass
Text Height	Fail
Text Style	Pass
Line Types	Fail
No Elements on Layer 0	Warning
Layer not in library list	Warning

Exit Next Report Previous Report Export Report

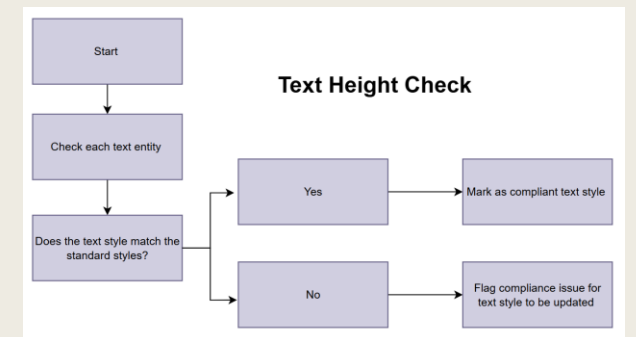
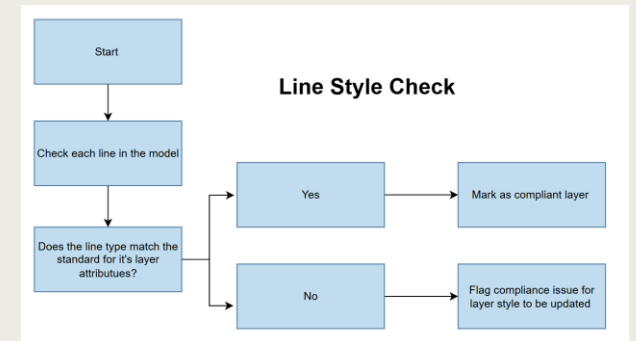
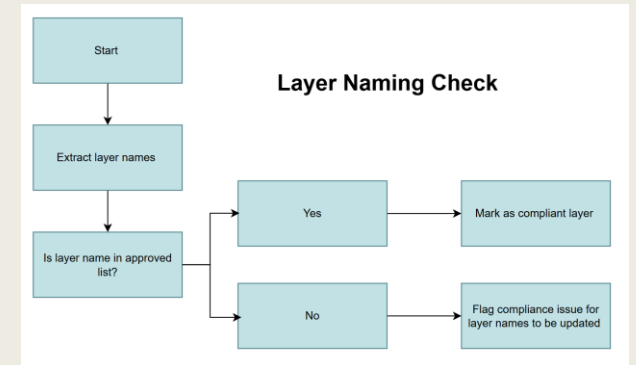
Architecture Diagram

- The architecture diagram provides an overview of the system structure and the relationships between core components.
- It shows how the user interface interacts with processing and validation features to generate outputs that help users correct CAD drawings and models.
- The diagram illustrates a modular design approach, allowing components to be developed, tested and improved separately to support prototype development.
- It highlights how data flows through the system, supporting scalability and enabling future improvements.



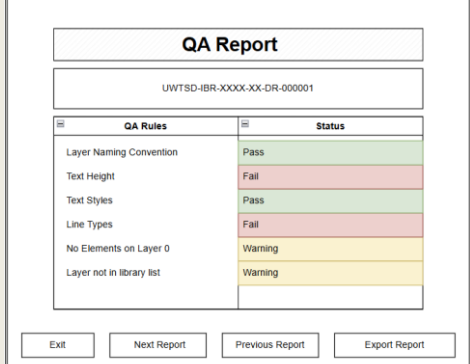
Validation Rule Flowcharts

- The validation rule flowcharts explain the decision-making processes used to evaluate CAD drawing elements against organisational standards.
- Each flowchart represents a specific validation rule that addresses common changes made to models or drawings after reviews.
- The diagrams show how the rule-processing engine interprets drawing and model data and applies conditional logic to determine compliance.
- They support transparency and maintainability, making it easier to expand the rule set in future iterations of the tool.



User Interface Design

- The user interface design shows how validation results are presented clearly and accessibly.
- The interface emphasises readability by highlighting detected issues with descriptions and colour indicators for passed checks, failed checks and warnings.
- The designs support quick decision-making during QA processes and help ensure the output meets user expectations.

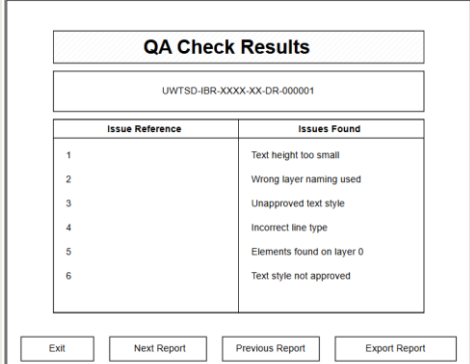


QA Report

UWTSO-IBR-XXXX-XX-DR-000001

QA Rules	Status
Layer Naming Convention	Pass
Text Height	Fail
Text Styles	Pass
Line Types	Fail
No Elements on Layer 0	Warning
Layer not in library list	Warning

Exit Next Report Previous Report Export Report

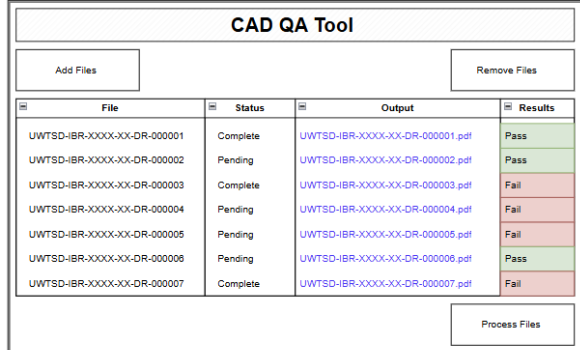


QA Check Results

UWTSO-IBR-XXXX-XX-DR-000001

Issue Reference	Issues Found
1	Text height too small
2	Wrong layer naming used
3	Unapproved text style
4	Incorrect line type
5	Elements found on layer 0
6	Text style not approved

Exit Next Report Previous Report Export Report



CAD QA Tool

Add Files Remove Files

File	Status	Output	Results
UWTSO-IBR-XXXX-XX-DR-000001	Complete	UWTSO-IBR-XXXX-XX-DR-000001.pdf	Pass
UWTSO-IBR-XXXX-XX-DR-000002	Pending	UWTSO-IBR-XXXX-XX-DR-000002.pdf	Pass
UWTSO-IBR-XXXX-XX-DR-000003	Complete	UWTSO-IBR-XXXX-XX-DR-000003.pdf	Fail
UWTSO-IBR-XXXX-XX-DR-000004	Pending	UWTSO-IBR-XXXX-XX-DR-000004.pdf	Fail
UWTSO-IBR-XXXX-XX-DR-000005	Pending	UWTSO-IBR-XXXX-XX-DR-000005.pdf	Fail
UWTSO-IBR-XXXX-XX-DR-000006	Pending	UWTSO-IBR-XXXX-XX-DR-000006.pdf	Pass
UWTSO-IBR-XXXX-XX-DR-000007	Complete	UWTSO-IBR-XXXX-XX-DR-000007.pdf	Fail

Process Files

Data Collection and Analysis

- The project uses qualitative and quantitative methods to understand current CAD QA practices and evaluate the prototype.
- Interviews, surveys and observations provide insight into workflows, drafting errors, user experience and manual QA checks.
- Technical evaluation uses draft engineering drawings processed through a Python 3.14 prototype with the ezdxf 1.3.x library to ensure replicability and compatibility.
- Expert evaluation from senior technicians and engineers assesses the clarity and relevance of validation outputs.
- Quantitative performance measures (processing time, issues detected, consistency) help judge the tool's effectiveness.
- Combining qualitative feedback and quantitative results provides a balanced assessment of the prototype's accuracy, usability and alignment with real-world QA needs.



Interviews



Surveys



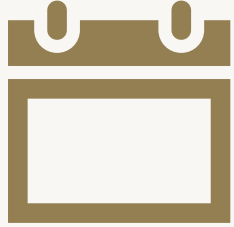
Observations



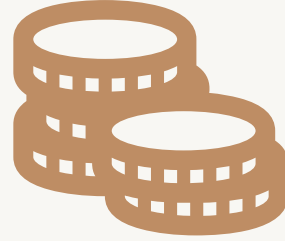
Technical Evaluation



Expert Evaluation



Time: September 2026 → July 2027 to cover all project stages



Budget: No financial budget required. Only existing tools and software licences



Resources: Laptop, Python, ezdxf, AutoCAD, Microsoft Office for coding, processing, documentation and analysis

Project Planning and Resources

Task	June		July		August		September		October		November		December		January		February		March		April		May		June		July	
1. Project Proposal																												
1. Research and Project Proposal																												
1 Develop Proposal Sections (topic, rationale, literature review, aim and objectives, methodology)																												
2 Draft Initial System Design and Workflows																												
3 Complete Ethical Approval Form																												
4 Finalise Project Proposal																												
5 Milestone - Project Proposal Submitted																												
2. Project Development																												
Requirements and Specification																												
6 Define Requirement (Functional and Non-Functional)																												
7 Establish Success Criteria and Minimum Viable Product																												
8 Conduct Risk and Resource Management																												
Detailed System Design																												
9 Architecture and Workflow Design																												
10 Validation Rule-Set and Data Structure Design																												
11 Prototype Development																												
Technical Setup																												
12 Configure Development and Test Environments																												
13 Select Library and Frameworks																												
14 Set up Version Control																												
Development																												
15 Develop Modules, Rule Engine and Interface																												
16 Integrate Components																												
17 Code Review and Internal Testing																												
18 Milestone: Core System Developed																												
Testing & Quality Assurance																												
19 Perform Unit, Integration and System Testing																												
20 Test CAD Files																												
21 Log and Fix Issues for Regression Testing																												
22 Milestone: Testing Phase Completed																												
User Evaluation & Feedback																												
23 Create Questionnaire and Collect Responses																												
24 Analyse and Summarise Feedback																												
25 Milestone: User Feedback Collected																												
Application Refinement																												
26 Implement Improvements and Re-test Features																												
27 Validate Rule Accuracy																												
28 Finalise Application Build																												
29 Milestone: Final Application Completed																												
Dissertation Writing																												
30 Write core chapters (Methodology, Design, Development, Test)																												
31 Update literature review and supporting diagrams etc																												
32 Proofread, format, and update references																												
33 Dissertation Submitted																												

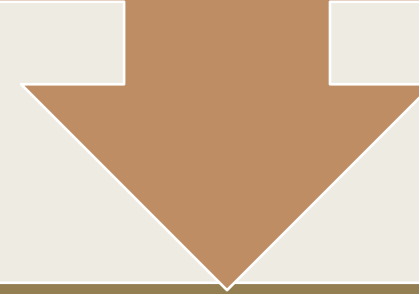
Project Milestones

- 1. Project Proposal Submitted → Deadline September 2026
- 2. Core System Developed → Deadline March 2027
- 3. Testing Phase Completed → Deadline April 2027
- 4. User Feedback Collected → Deadline May 2027
- 5. Final Application Completed → Deadline June 2027
- 6. Dissertation Submitted → Deadline July 2027

Impact and Limitations

Impact

- Reduces time spent manually reviewing plans and models, improving workflow efficiency.
- Supports more consistent adherence to drafting and QA standards.
- Produces more accurate and reliable engineering deliverables across the organisation.
- Strengthens overall quality assurance by increasing attention to validation checks.



Limitations

- Data dependency may affect how reliably the tool performs across different projects or disciplines.
- Computational cost could increase with larger or more complex models.
- Robustness and interpretability of automated checks may vary depending on rule complexity.
- Training instability highlights challenges in scaling and refining an automated assurance tool.

Further Developments

Once a working prototype is available and user feedback has been collected from technicians and engineers, the QA tool could be enhanced in future design iterations to include additional validation rules and improve its scalability. Examples of the future improvements include:

1. Checking and reviewing multiple models, drawings and combined models
 2. Providing suggestions for moving annotations to avoid clashes in plan
 3. Creating the first pass of a markup for technicians and engineers to add their own comments
 4. Improve compatibility with a wider range of software such as Bentley MicroStation and OpenRoads, Tekla, Revit and Grasshopper.
 5. Create an online QA tool that can be used within design applications rather than using an offline version
 6. Automatically run the QA tool at the end of every day and apply live version control tracking features
 7. Include project specific validation rules
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Summary

 Background and Rationale

 Literature Review Summary

 Aim and Objectives

 Research Methodology

 Technical Approach and System Design

 Project Planning and Resources

 Impact and Limitations

 Further Developments

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