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Permit-Ready by Design: A Quantitative Checklist Framework to Reduce Municipal Water/Wastewater Resubmittals

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Abstract

Municipal water and wastewater projects must be submitted with comprehensive, coordinated, and traceable documents, but no readily available pre-submission quality-control metric exists. This research introduces a 30-item Permit Readiness Index (PRI) with six different weighted domains that are based on the primary needs and requirements of agencies in the United States as well as water utilities. This study compared the feasibility of analyzing public records and is a source-linked, purposive audit of 20 completed water-supply construction permits from Iowa and 20 water or wastewater correction comments received by the City of Tucson. The median interval from receipt to review was 30.5 calendar days (interquartile range [IQR] 22.75–51.00), and the median interval from receipt to finalization was 53.0 days (IQR 27.75–99.75). The study categorized significant comments into eight pre-established deficiency categories, and the number of comments in each category was illustrative only because the categories were intentionally diversified. In an ancillary analysis limited to pumpers living within the treatment and water-main boundaries in Iowa, the odds ratio for treatment water versus the combined treatment+storage/pumping cohort for finalization on the 60-day treatment time was 6.00 (95% Wald CI 0.81–44.35; p = 0.079). Apparent receiver operating characteristic area under the curve (ROC-AUC) was 0.708, versus 0.500 under leave-one-out prediction. Agreement between a project-type timing heuristic and the observed binary delay outcome was Cohen's κ = 0.400; this is not an inter-rater reliability estimate. The PRI incorporates explicit 0/1/2 evidence rules, conditional critical-fail overrides and author-proposed 15/20/25/15/15/10 domain weights. Sensitivity scenarios demonstrate that weights and thresholds affect screening classifications. Since complete pre-submission plans, observed PRI scores, independently duplicated Tucson coding and matched first-cycle approval/resubmittal outcomes were unavailable, the PRI's predictive validity and effect on resubmittals remain unestablished. The contribution is an auditable screening protocol and a reproducible, explicitly limited empirical process audit.

Keywords: Permit Readiness Index, Municipal Water and Wastewater Permitting, Permit Resubmittals, Pre-Submission Quality Control, Regulatory Compliance, Engineering Design Review.

1. Introduction

Public investment requirements underscore the importance of dependable water and wastewater design review. The U.S. Environmental Protection Agency (EPA) estimated approximately $625 billion in national drinking-water infrastructure needs over 20 years in its seventh Drinking Water Infrastructure Needs Survey and Assessment (U.S. Environmental Protection Agency,, 2023); (U.S. Environmental Protection Agency). EPA's 2022 Clean

Watersheds Needs Survey reported $630.1 billion in clean-water needs, including $151.1 billion for conveyance-system rehabilitation and expansion, and identified 17,544 publicly owned treatment works serving approximately 270.4 million people (U.S. Environmental Protection Agency, 2026). These needs involve significant engineering design and permitting work. A permit-by-design approach therefore also focuses on strict, verifiable technical calculations and ensures documents are complete, design inconsistencies are addressed, and other agencies are coordinated before submitting for a permit.

Municipal plan examination can catch incomplete calculations, missing/conflicting drawings, inaccurate utility information, inadequate hydraulic evidence, easement and right-of-way issues, coordination deficiencies, and failed at or incomplete ways to address issues raised in prior comments. The City of Phoenix has plan checklists for water-main plan amendments and sanitary sewer-main plan amendments, and Denver Water requires amended water plans to be accompanied by a written response to redline comments. These requirements support a structured completeness assessment but do not create a numerical readiness score that equates to a permitting decision. The current study recognizes the difference between the score's design and the empirical evidence on its performance in predicting reactions.

The objectives of this study are to:

1. Recognize and categorize major technical, administrative, documentation and coordination issues noted by municipalities in the comments on water/wastewater resubmittals.
2. Develop a shared 100-point Permit-Readiness Index (PRI) based on iterative requirements from all authoritative municipal, state, and federal permitting review checklists.
3. Identify observables related to permit processing and provide publicly available water and wastewater code, including denominators and limitations.
4. Operationalize a 30-item30-item, 100-point pre-submission PRI with evidence-based scoring, critical-fail conditions, and sensitivity to proposed weights and decision thresholds.

The study targets the municipal water and wastewater system, including water-main projects, sewer extensions, pump/lift stations, water-treatment projects, wastewater-treatment projects, and extensive water and wastewater utility or site infrastructure. It focuses on the quality of the engineering design and permitting outcomes, rather than construction inspection or field performance activities. The primary sources of empirical evidence are publicly available U.S. regulatory and municipal databases. To maximize the generalizability of a proposed permit-readiness checklist, it includes necessary steps from multiple jurisdictions and avoids duplicating memorized procedures for a single municipality. The analysis thus focuses on common features of the plan review and resubmittal process that can be objectively observed in the designs and plan review documentation.

The paper comprises six main sections. Section 2 analyzes literature on design rework, plan review, and compliance checks. Section 3 outlines the public-record audit, coding procedures, statistical analysis, and limitations. Section 4 establishes the quantitative checklist and the workflow used for internal quality control. Section 5 presents data from a descriptive audit, exploratory timing model, and screening sensitivity analysis, along with interpretations. Section 6 concludes the study and summarizes findings, implications, limitations, and

recommendations. The appendices provide source-identified record numbers for independent record checks.

2. Literature Review

2.1Design Rework, Review Cycles, and Infrastructure Delivery

These design deficiencies may require drawing corrections, coordination activities, reevaluation of calculations, and reexamination of the regulation. Resubmittal refers to resubmitting material, such as corrected material requested as part of the approval process, whereas rework refers to redoing the physical or design components of a project during delivery; these occur at different stages and should not be treated as the same phenomenon (Matthews, Love, Ika, & W. Fang, 2022). Their consequences are different but can be caused by omissions, inconsistent specifications, poorly supported calculations, and unresolved utility interfaces. The principle of quality control is that demonstrable mistakes will be found while the design package remains under the engineer's control.

The literature highlights published research on clash detection and retrospective point-cloud-based modeling showing that BIM can identify design gaps before construction (Bashir, Ahmad, Lee, Shah, & M. Awang, 2025); (Lawani, Sadeghineko, Tong, & M. Bayraktar, 2025). These building-sector findings continue to provide a quality-control rationale but do not provide a specific reduction in municipal water/wastewater review comments, permit resubmittals, or plan examiner hours. The more limited implication is that early, auditable checks can identify drawing, calculation, and coordination problems which can then be reworked within the design team.

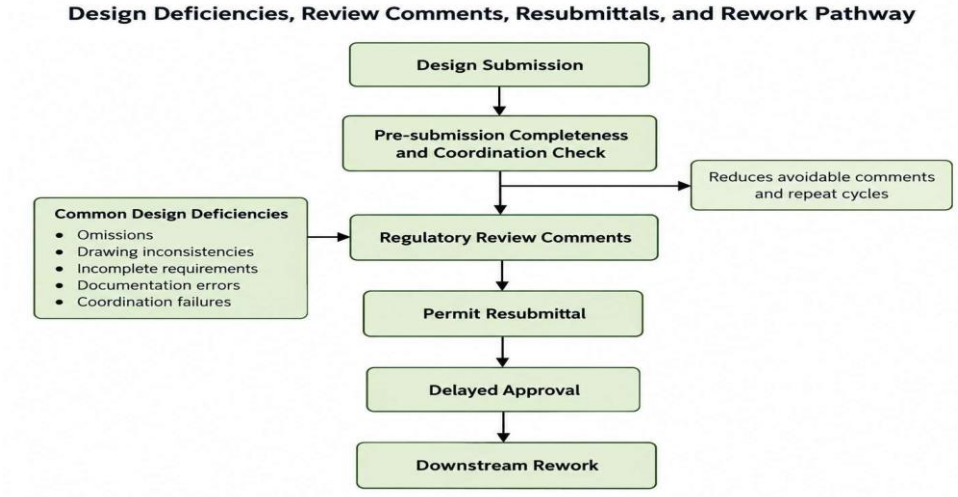


Figure 1: Pathway linking design deficiencies, regulatory comments, resubmittals, delayed approval, and downstream rework.

Figure 1 shows a conceptual route from design deficiencies to comments made during the plan review and the multiple iterations through the process, to eventual approval and, if it occurs, downstream rework. The pathway is not a proposed causal model, but rather an explanatory pathway. The pre-submission control point provides a chance to spot inconsistent drawings, incomplete supporting details, or unresolved coordination issues; any reduction in reviewers or review rounds, or in construction rework, would require a post-submission check of observed construction outcomes.

2.2Existing Water and Wastewater Plan Review Requirements

Public Water & Wastewater Design Guidance (PDG) translates statutory and technical obligations into checkable design elements in drawings, specifications, calculations, applications, approvals, and coordination records. The City of Phoenix offers separate plan checklists for sewer mains and water mains (City of Phoenix Planning and Development Department, 2021). Austin Water's official Water and Wastewater Tap Plan checklist includes the following mandatory professional engineering information, existing utilities, main and service characteristics, water demand, and wastewater elevations and connection details (Austin Water, City of Austin, 2018). These documents provide primary evidence for the proposed checklist domains but not evidence of the PRI's effectiveness. Denver Water specifies water-plan submittal procedures and responses to marked-up plans (Denver Water). Oregon Department of Environmental Quality guidance addresses wastewater engineering-plan review and required supporting documentation (Oregon Department of Environmental Quality). Alaska Department of Environmental Conservation publishes drinking-water engineering-plan completeness checklists (Alaska Department of Environmental Conservation). Collectively, the sources require evidence of technical adequacy and

administrative completeness, although detailed design criteria and approval responsibilities vary between agencies.

The primary requirements provide rationale for screening structure across jurisdictions, rather than for an across-the-board permit-approval threshold. The proposed controls should then be compared with applicable regulations, area standards, and the permit pathway for the particular project. The EPA National Pollutant Discharge Elimination System (NPDES) application guidance adds additional examples of those information and authorization provisions that may be included in a waste discharge permit but that do not constitute a state construction-permit approval or a municipal water-main approval (U.S. Environmental Protection Agency). Table 1 summarizes the respective agency requirements and their practical scope.

Table 1: Summary of Existing Water and Wastewater Plan Review Requirements

Reviewing authority	Main plan review requirements	Practical emphasis
Phoenix Water Services	Formal water and sewer plan checklists	Minimum submission completeness and consistent review
Austin Water	Existing and proposed mains, pipe size and material, wastewater flow direction, service extensions, utility conflicts, and construction notes	Technical completeness and utility coordination
Denver Water	Engineering and CAD standards, revised drawings, and documented responses to plan examiner comments	Drawing quality, standards compliance, and resubmittal traceability
Oregon DEQ	Plans, specifications, engineering documentation, and design information for gravity sewers and pumping facilities	Engineering documentation and technical design
Alaska DEC	Completeness checklists before substantive review	Early completeness screening and reduced processing delays
Cross-jurisdiction implication	Administrative, geometric, hydraulic, documentation, coordination, and approval requirements	Permit readiness requires multiple coordinated checks rather than a single technical calculation

2.3Digital Review, Quantitative Compliance, and Checklist-Based Quality Control

Recurring review requirements are now measurable controls with the advent of digitalization. Structured compliance checking is based on observable requirements and pass/fail or graded conditions, recording exceptions and design evidence to support review decisions (García, Toledo, Aragonés, & L. Bañón, 2026). Several principles in this study are not expanded to a claim that automated municipal permit approval is achieved, but rather to a manually auditable design-package checklist.

Water and wastewater permit packages may incorporate plan sheets exported from computer-aided design systems, calculation reports, specifications, professional certifications, agency authorizations and responses to earlier plan-examination comments (Wang, et al., 2024). Not every criterion can be evaluated mechanically: site conditions, design alternatives and jurisdictional discretion may require professional engineering judgment. Accordingly, the proposed PRI uses an auditable manual scoring protocol with explicit evidence references and does not claim to automate substantive permit authorization. Table 2 describes the functions that support this approach.

Table 2: Digital compliance pathway linking measurable controls, automated logic, and professional review decisions

Component	Digital or Control Function	Practical Application
Observable conditions	Converts requirements into measurable checks	Enables consistent compliance assessment
Pass or fail states	Defines whether requirements are satisfied	Supports objective screening
Exception recording	Captures identified deficiencies	Helps prioritize corrective actions
Traceability	Links deficiencies with responses and corrections	Provides an auditable review trail
Automated control logic	Uses predefined rules and thresholds	Supports repeatable compliance checking
Digital design documents	Uses PDFs, CAD drawings, calculations, and specifications	Provides evidence for technical review
Professional judgment	Evaluates context dependent conditions	Addresses site constraints and engineering alternatives
Quantitative checklist	Assigns structured scores to verifiable requirements	Provides practical pre submission quality control

2.4Research Gap and Limitations in Existing Literature

Recent studies in infrastructure quality management and digital compliance checking have developed methods to control design flaws and document conformance (Urban, Fischer, & C. Schranz, 2024). However, results from construction rework, building-information modeling, or building-permit automation should not be used as a direct benchmark for whether a water/wastewater pre-submission checklist can reduce regulatory resubmittals. A measure of permit-readiness must be directly testable, meaning it must have defined items at the inspection level, equal project-level scoring, and have regulatory outcomes that are observed on a comparable cohort.

Categories, review units, and decision outcomes vary across agencies, and existing plan-examination data may reflect common problems. Published checklist requirements can quantify the relationship between initial design completeness and the number of review cycles. This study therefore defines an operational screening instrument, records two distinct public-record audit trails, and outlines the future data relevant to evaluating the PRI's

reliability, calibration, and discrimination.

3. Methods and Techniques

3.1Data Collection Methods and Data Sources

Two source-linked public-record audit streams and six agency guidance groups were used. Dataset A comprised 20 distinct Iowa Department of Natural Resources Water/Wastewater Information System and Records Database (W/WISARD) water-supply construction-permit entries with publicly visible receipt, review and final-action dates (Iowa Department of Natural Resources). Records were received between January 2025 and May 2026 and finalized by 30 June 2026; ten were categorized as linear water-main projects and ten as treatment, storage or pumping projects. The selection was purposive, limited to indexable, sufficiently documented entries, and was not intended to represent a statewide random sample. One finalized action was retained per project. Dates and permit decisions were transcribed from the official record, with URLs and identifiers retained in Appendix A. These records support elapsed-time analysis only; they do not disclose the pre-submission plan evidence needed to assign PRI scores.

3.2Resubmittal Comment Dataset and Deficiency Coding

Dataset B comprised 20 City of Tucson PRO public plan-examination records with a visible water-, sewer-or plumbing-related correction comment and case identifier (City of Tucson); (City of Tucson Planning and Development Services). The audit used a purposive set of unique permit/plan identifiers and deliberately sampled across eight prespecified categories: administrative completeness; drawings and document control; hydraulic or design calculations; technical water/wastewater design; utility coordination; easements or external approvals; standards compliance; and response traceability. For each case, one salient comment was paraphrased and assigned one mutually exclusive primary category; other comments on the same case were not included in the frequency count. The municipal source includes commercial plumbing and development cases and is not coextensive with the Iowa state construction-permit program. Appendix B lists the 20 identifiers, coded observations and original public URLs. Category frequencies represent the selected examples, not a population estimate for Tucson.

The coding unit was one publicly visible correction comment, linked to a specific public case. Classification used the eight-category codebook and a single primary-code rule. Because the source record was sampled by category for illustration and no second assessor independently coded the same observations, the audit cannot support either a representative Pareto estimate or an inter-rater Cohen's κ for deficiency classification (J. Cohen, 1960). Table 3 documents the actual observation units, inclusion rules and limitations.

Table 3: Traceable Tucson comment-audit definition, coding rules, and limitations

Element	Audited evidence or decision rule	Interpretation
Documented audit	20 distinct Tucson PRO review-detail cases; dates 2024–2025; URLs in Appendix B	Purposively selected examples; no population-frequency inference
Eligibility	Visible Requires Resubmit/correction; identifiable water/sewer/plumbing issue	Includes mixed commercial-plumbing and development approvals
Unit of coding	One selected, relevant plan examiner comment per unique record	Not all comments or all review rounds per project

Deficiency taxonomy	Eight explicit classes; one mutually exclusive primary category	Supports arithmetic frequencies for the 20 selected comments only
Outcome composition	Cases deliberately identified through deficiencies	No first-pass-approval control group; no predictive comparison
PRI evidence	Complete initial design-package files and scored checklists unavailable	Actual PRI scores cannot be assigned retrospectively
Coder replication	One audit coding pass; no independently recoded cases	Inter-rater kappa not estimable; Iowa timing concordance is separate

3.3Quantitative Data Analysis

The quantitative analysis was conducted in four phases. The study first determined the receipt-to-review and receipt-to-final-action times for Dataset A in elapsed calendar days, then summarized those times using medians, ranges, and 25th–75th percentiles obtained by linear interpolation. The study coded the 20 selected Dataset B comments by deficiency type, reported illustrative cumulative percentages, and displayed the results in a table. It also conducted an exploratory association analysis in Iowa alone examining the association between infrastructure type and an author-informed prolonged finalization indicator. Four predetermined hypothetical score profiles were also assessed to determine arithmetic decision sensitivity using alternative PRI weights and cutoffs. The rows for Iowa and Tucson were not pooled, and no project-level unobserved checklist score/comment count/review cycle was imputed.

The timing outcome was defined as>60 calendar days from agency-recorded receipt to final action. This is an analytical threshold, not the regulatory service-level reference value chosen by the pilot. The binary predictor was treatment/storage/pumping (1) or linear water-main infrastructure (0). The maximum likelihood logistic regression model used was logit[P(finalization > 60 days)] = alpha + beta (project-type indicator); reported results were: regression coefficient, odds ratio (OR), Wald 95 % confidence interval (CI), Wald p-value, and Fisher exact test result for the corresponding 2 × 2 table.

Discrimination was summarized by apparent ROC-AUC and a case-resampling percentile CI (10,000 replicates). A leave-one-out assessment trained an L2-regularized logistic regression on 19 cases at a time and predicted the held-out record; out-of-fold ROC-AUC and Brier score were then computed. These analyses concern finalization time, not resubmittal or PRI scores (Collins, Reitsma, Altman, & K. G. M. Moons, 2015); (Moons, Altman, Reitsma, & et al., 2015).

For the same Iowa timing outcome, an exploratory categorical-concordance check treated infrastructure type as a fixed binary alert (facility = predicted prolonged finalization; water main = predicted nonprolonged finalization). Sensitivity, specificity, overall concordance and Cohen's κ were calculated from the observed alert/outcome contingency table; $\kappa = (p_o - p_e)/(1 - p_e)$, where p_o is observed agreement and p_e is chance-expected agreement based on margins (J. Cohen, 1960). A case-pair bootstrap yielded a percentile CI. This application of κ measures agreement of a heuristic with a recorded outcome; it is neither a measure of two independent assessors' reliability nor validation of the PRI. All inferential estimates are exploratory because the sample is small and purposively selected.

3.4Reliability, Validation, and Limitations

The Tucson comments were classified once, without an independently duplicated

coding set. Inter-rater percentage agreement and inter-rater Cohen's κ for the eight-category deficiency codebook are therefore not estimable from the available observations (K. A. Hallgren, 2012). The κ reported for the Iowa timing heuristic addresses a different, explicitly defined two-variable comparison. A genuine reliability study should use at least two independently trained, blinded coders, a fixed sampling frame, retained item-by-item classifications, a full cross-tabulation and a confidence interval for nominal-code κ. Ordinal 0/1/2 PRI item scores would additionally warrant an ordinal agreement statistic. The various types of agreements reflect different concepts and should not be merged.

Internal validity constraints include purpose-built case selection, a small water-supply-only Iowa sample, deliberate diversity of Tucson project types, and variation in project complexity, and the inability to distinguish applicant turnaround from agency work time. Public databases might not include informal communications, mid-development review cycles, design attachments, or actions that are taken as part of an alternate between-agency process. Iowa state construction-permit decisions and Tucson municipal building/development correction comments do not share the same outcome definition and cannot be matched to create a predictive cohort.

Confounding is especially relevant in the ancillary model because treatment and pumping facilities can have different magnitudes of technical and coordination requirements than water mains. Finalization time may also be extended beyond the impact of initial package quality due to owner-directed changes, external approvals, and unexpected site conditions. Because there are no date-locked source plans, no observed PRI scores, and no outcome-complete comparison group or independent duplicate classifications, the current data do not prove that PRI is associated with a reduced probability of resubmittal and shorter review durations. Table 4 specifies the actual units and analytical uses.

Table 4: Verified source-linked audit streams, units, outcomes and validation limits

Stream	Unit	Period	Variables directly verified	Selection / analytic role	n
Iowa W/WISARD	Finalized water-supply permit entry	2025–June 2026	Receipt, review, final dates; category; permit decision	Purposive, dated public entries; elapsed-day audit ONLY	20
Tucson PRO	One comment per review case	2024–2025	Permit ID; resubmit/correction text; primary class	Purposive 8-class illustration; cannot estimate general prevalence	20
Agency guidance	Original checklist/permit documents	Sources current at review	Submission requirements by authority	Develop 30-item PRI; NOT project-level observations	6
Independent-code replication	Not available	Not available	No independently paired eight-class coding observations	Inter-rater agreement cannot be estimated from the audit	0

4. Quantitative Permit-Ready Checklist Framework

4.1Framework Development

The framework was constructed by extracting recurring plan-submission and technical-document requirements from the City of Phoenix, Austin Water, Denver Water, Oregon DEQ and Alaska DEC, with EPA NPDES materials used only where documentation and discharge-permit controls are applicable (City of Phoenix Planning and Development Department, , 2020);

(City of Phoenix Water Services,). Requirements were mapped into six design-quality domains: administrative completeness; design basis/calculations; water and wastewater technical design; drawings/specifications/constructability; utility and external-agency coordination; and

quality assurance/comment-response traceability. Five operationally specified controls were placed in each domain, generating 30 assessable items. Item selection and weighting were based on engineering judgement without transparency, and no statistical frequency-derived weighting or formal elicitation using the Delphi/AHP method is claimed. The complete instrument is fully presented in Table 4A.

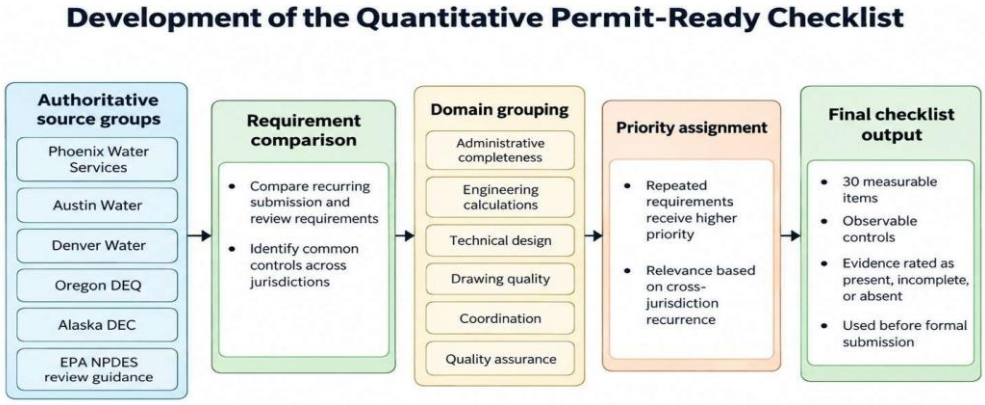


Figure 2: Development pathway for transforming recurring regulatory requirements into a quantitative checklist framework

Figure 2 illustrates the proposed process, from the authoritative agency's needs to grouping, prioritization, and domain-level operational controls. The organization had come about as a result of cross-agency thematic similarity, and no empirical association between the items on the checklist and subsequent outcomes had been assumed. Table 4A provides the needed extra information for each control, including the incomplete-evidence state, agency-source mapping, and conditional critical-fail designations.

4.2Permit Readiness Index

The PRI is a domain-normalized score from 0 to 100. Each of the six provisional domain weights is 15 points for administrative Completeness & Authorization (A), 20 points for design Basis & Calculations (B), 25 points for water/wastewater Technical Criteria (C), 15 points for drawings, specifications, CAD, and constructability (D), 15 points for utility, interagency & easement coordination (E), and 10 points for quality Assurance & comment-response traceability (F). The allocation uses engineering consequence rather than prediction-model coefficients estimated from data, and it places the greatest weight on engineering adequacy and analytical support. Weights sum to 100 points and require independent calibration before any claim of optimality.

Each applicable item is scored 2 when all listed requirements are substantiated by identifiable, internally consistent evidence; 1 when relevant evidence is present but materially incomplete; and 0 when the requirement is absent or noncompliant. A not-applicable (N/A) designation requires a project-specific technical or legal justification recorded and approved by the engineer of record. For domain d, let n_d denote its applicable items and $s_{id} \in \{0,1,2\}$ their scores. Then $R_d = (\Sigma_i s_{id})/(2n_d)$, and $PRI = 15R_A + 20R_B + 25R_C + 15R_D + 15R_E + 10R_F$. For a

domain with n_d = 0, an approved project-specific allocation must be made instead of automatic full credit in order to calculate PRI. The scoring record shall include document references, assessor, date, exceptions, and corrective action. A critical failure will be judged independently and cannot be compensated for elsewhere.

The critical-fail designation "YES*" in Table 4A only applies if the requirement indicated in the table is legally or technically required for the particular pathway for a permit being assessed. The agency abbreviations include P (Phoenix), A (Austin Water), D (Denver Water), O (Oregon DEQ), K (Alaska DEC), and E (EPA NPDES forms) for which discharge-permit documentation is relevant. Partial-credit examples are internal quality-control classifications, not statements that an agency must accept the design.

Table 4A: Thirty measurable PRI controls, operational scores, conditional critical-fail flags and primary-source mapping

ID	Required evidence/control	Score 2: complete evidence	Score 1: incomplete evidence	CF?	Agency
A1	Applicant, owner, project location and scope identical across form/cover sheet	All required identifiers and scope verified	Minor identifier discrepancy or missing cross-reference	No	P,A
A2	Current signature, registration and professional seal	Required valid signature/seal verifiable on deliverables	Seal or date shown but one required attribute unclear	YES*	P,D,O
A3	Complete permit package: forms, plans and specifications	Every jurisdiction-required document indexed and attached	One noncritical required document incomplete	YES*	P,A,D,O,K
A4	Permit pathway, fees and application attachments	Correct application route, fees and listed attachments evidenced	Supporting fee or route evidence incomplete	No	P,A,O
A5	Versioned design and document register	Package has dated sheet/revision register matching files	Register present with unresolved version mismatch	No	D,K
B1	Demand/flow and design-basis memorandum	Flow, loading, criteria and assumptions cited and consistent	Assumptions noted but one supporting value missing	No	A,O
B2	Hydraulic grade/pressure/flow capacity calculations	Applicable network and pressure/flow computation checked	Computation present but boundary case not resolved	YES*	P,A,O
B3	Sewer design flow, slope, capacity and velocity	Gravity sewer calculations satisfy applicable criteria	Selected reach/load case not justified	YES*	A,O
B4	Pumping duty, total head and redundancy	Pump curve/duty/standby and head losses documented	Duty point evidenced but reserve/controls incomplete	No	O,K
B5	Treatment, storage or process sizing calculations	Required capacity, detention or process sizing checked	Process sizing shown but one design case open	No	O,E
C1	Water main sizes, classes, pressure and material	Selected pipes and pressure class meet local standards	One schedule/standard evidence unresolved	No	P,A
C2	Sewer pipe, cover, grade and manhole criteria	Sizes, slopes, cover and manholes demonstrated	One run/profile criterion still unconfirmed	No	A,O

ID	Required evidence/control	Score 2: complete evidence	Score 1: incomplete evidence	CF?	Agency
C3	Water/wastewater treatment performance criteria	Applicable process and disinfection requirements evidenced	Treatment criterion cited without complete verification	No	O,E
C4	Water-sewer separation, backflow and cross-connection	Required separation and approved protection documented	Separation/protection partly shown but unverified	YES*	P,A,O
C5	Operations access and maintainable equipment layout	Access/clearances and O&M provisions checked	Maintainability shown with an unresolved clearance	No	A,O
D1	Plan/profile alignment, scale and key elevations	Plans/profiles have matching stations, scales and datum	One coordinate or grade annotation unresolved	No	P,A
D2	Cross-sheet consistency of sizes and invert levels	All civil, piping and plumbing depictions reconcile	Single schedule or detail differs across sheets	No	P,A,D
D3	Valves, manholes, connections and construction details	Required details are keyed on drawings	One detail or keyed reference incomplete	No	P,A
D4	Material schedules and specifications match drawings	Tables, specs and plans agree for scope and materials	Minor unsynchronized specification detail	No	P,D
D5	CAD sheet standards, title blocks and revisions	Complete dated sheets comply with submitting agency	Minor CAD labeling or revision mismatch	No	D,P
E1	Existing utility surveys and owner coordination	Utility locations and owners identified/recorded	Utility record supplied but alignment unconfirmed	No	A,D
E2	Material utility clashes and crossings resolved	All significant conflicts have signed feasible solutions	Material conflict remains only partly resolved	YES*	A,D
E3	Water/sewer connection points and service capacity	Tie-in locations and capacity/acceptance documented	Connection depicted but capacity confirmation missing	YES*	A,O
E4	Recorded easements, rights-of-way and site access	All legally required property rights attached	Required access instrument pending	YES*	A,O
E5	Required county, environmental and agency approvals	All mandatory external consents supplied	One legally required consent still pending	YES*	A,O,E
F1	Designer-led documented completeness review	Signed self-check cites evidence for all applicable items	Checklist filled but some citations missing	No	P,D
F2	Independent discipline quality review	Named checker has signed/date-stamped completed record	Peer check conducted but unresolved notes remain	No	D,K
F3	Closed revision/change issue register	All dispositions cross-link to revised sheets	Open minor item lacks closeout evidence	No	D,K
F4	Item-by-item written response to prior redlines	Every plan examiner point answered with sheet/detail reference	One response incomplete or missing a trace	YES*	D

ID	Required evidence/control	Score 2: complete evidence	Score 1: incomplete evidence	CF?	Agency
F5	Engineer-of-record release of matching deliverables	Released calculation/spec/drawing versions concordant	EOR sign-off pending synchronization	No	D,P

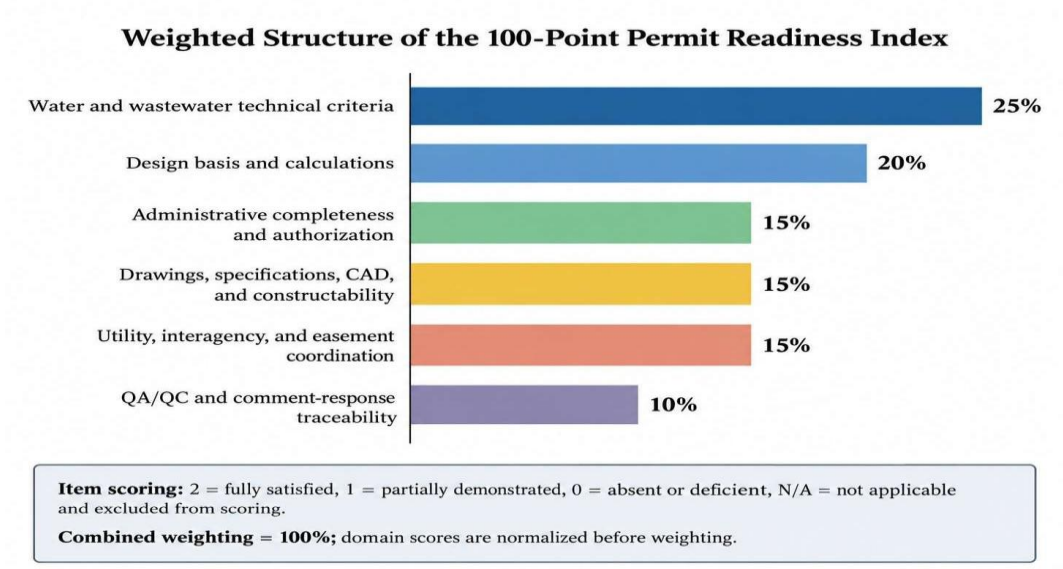


Figure 3: Weighted domain structure of the Permit Readiness Index framework

Figure 3 shows the author-assigned domain weights and the item-level evidence scale. Empirically estimated values for relative weights have not been determined. Hence, nominal categories should be read as internal release decisions tentatively made based on the data rather than as the probability of receiving the permitting decision. Table 4B illustrates how one evidence profile changes when two weights or thresholds vary.

4.3Critical Fail Requirements and Decision Thresholds

Critical-fail controls are unique controls in their own right and not compensatory release gates. These include professional-engineering registration, signature and seal (A2), submission package complete within jurisdiction (A3), required hydraulics/wastewater analyses (B2–B3), required water/sewer separation/backflow provisions (C4), connections/tie-ins feasible (E3), easements secured (E4), outside agencies approvals secured (E5), and comments on revised submissions documented (F4) for project-specific applicability. If any mandatory item is missing, or if the content for any item is substantially noncompliant, it does not qualify for internal release. It is also referred for corrective action and engineer-of-record confirmation.

Three bands of internal readiness are proposed by the authors: a PRI of 80–<90 or conditionally ready, with additional checks needed before permitting; a PRI of <80, indicating an elevated risk of checklist deficiency; and a PRI of 90–100 or permit-ready candidate. These bands are not regulatory threshold limits and have not been correlated with first-cycle acceptance/resubmittal data. The study recalculated four complete six-domain hypothetical profiles with weights (10,20,30,15,15,10) by shifting five points from administrative completeness to technical criteria; we also recalculated them using more stringent cutoffs (95,85) and more lenient cutoffs (85,75). Numerical scores and category changes for this result are shown in Table 4B.

Sensitivity Profiles are based on the condition in which all 5 controls in each domain are engaged, and there is no critical-fail override. Normalized A–F domain scores were specified as profile A (1.0, 0.9, 0.8, 0.9, 1.0, 0.9), B (0.9, 0.8, 0.8, 0.8, 0.8, 0.9), C (0.8, 0.8, 0.8, 0.8, 0.8, 0.8) and D (0.8, 0.8, 0.7, 0.8, 0.8, 0.8). They develop an arithmetic

scenario value, rather than an Iowa or Tucson PRI value.

Table 4B: Author-defined PRI sensitivity analysis for four hypothetical project profiles

Profile	Baseline PRI / 90-80	Weight-shift PRI / 90-80	Strict 95-85	Relaxed 85-75
A	90.5 / Ready	89.5 / Conditional	Conditional	Ready
B	82.5 / Conditional	82.0 / Conditional	Elevated	Conditional
C	80.0 / Conditional	80.0 / Conditional	Elevated	Conditional
D	77.5 / Elevated	77.0 / Elevated	Elevated	Conditional

The weight shift in profile A under the five-point equilibrium is 89.5 and crosses the provisional weight release line of 90 points. Profiles B and C are given the lowest classification, while D's classification is moved up because of its 85/75 cutoff. As a result, classification can be susceptible to policy decisions near boundaries. The exercise illustrates the scoring mechanics, but not sensitivity, specificity, or calibration against observed permitting outcomes.

4.4Practical Pre-Submission Workflow

The sequence of implementation involves an intra-check by the implementing designer and an evidence register that is indexed using the 30-item instrument. An independent discipline lead reviews and approves documentation, calculations, coordination records, and N/A documentation. The domain scores are then produced, and the composite PRI is calculated, including an individual assessment for critical failure. Any unaddressed critical failure, or any score below an organization's preset release criteria, must be corrected, re-verified, and recalculated. The final submission is approved by the engineer of record, and the regulatory agency has the final say in determining regulatory acceptance.

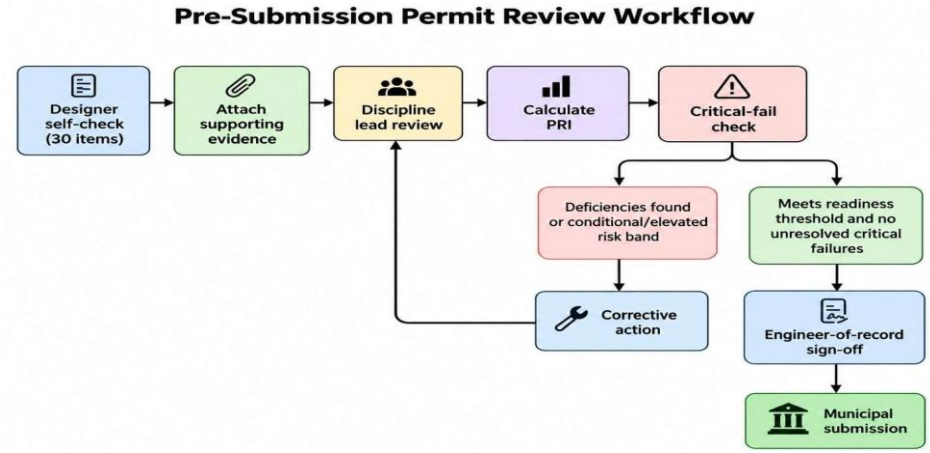


Figure 4: Pre submission permit review workflow for readiness and corrective action

Figure 4 provides an overview of the designer operational control loop, from designer self-check to evidence review, PRI scoring, critical failure assessment, and corrective action. After the blocking items are closed, the engineer of record must sign off. The workflow is an implementation proposal, and no reduction has yet been recorded in plan-examination hours, cycles of review, or resubmittals that have been made because of its application.

5. Results and Discussion

5.1Baseline Review and Resubmittal Performance

Table 5 presents the two observed datasets without combining the denominators. The Iowa audit includes 11 water-supply finalized construction permits, and 33 calls were source-linked, with half linked to linear water mains and the other half to treatment/storage/pumping facilities. Because the inclusion rules required identifiable finalized permits, the 100% for all 20 entries should not be interpreted as Iowa's approval rate. The separate Tucson audit contains one selected correction comment from each of 20 public plan-examination cases, by construction, and cannot estimate the frequency of adverse outcomes across all city submissions. Neither source supplies the pre-submission item-level documentation needed to calculate actual PRI scores.

Table 5: Verified case composition and denominators (two distinct, non-comparable public-record audits)

Characteristic	Description	Verified n	Share within source (%)
Iowa DNR W/WISARD	Distinct publicly linked water-supply permit entries	20	100.0
Iowa / linear	Water-main permits	10	50.0
Iowa / non-linear	Treatment, storage or pumping permits	10	50.0
Iowa / final action	Permitted (deliberate finalized-permit selection)	20	100.0
Tucson PRO	Distinct comments / one per public review case	20	100.0
Tucson / comment selection	Water/sewer/plumbing relevant and correction/resubmit	20	100.0
External combined sample	Not constructed: source groups have distinct units and outcomes	Not applicable	Not applicable

For the Iowa sample (n = 20), the median receipt-to-review time was 30.5 calendar days (IQR 22.75–51.00; range 3–311) and the median receipt-to-final-action time was 53.0 days (IQR 27.75–99.75; range 4–413). Among water-main projects (n = 10), corresponding medians were 25.5 days (IQR 22.25–32.25) and 31.5 days (IQR 26.25–54.50). Treatment/storage/pumping projects (n = 10) had medians of 45.5 days (IQR 30.25–73.00) and 102.5 days (IQR 48.50–182.25), respectively. Percentiles were linearly interpolated; these

figures describe elapsed intervals and should not be interpreted as active examination hours. Because selection was purposive, group differences are descriptive only. Individual source dates are in Appendix A; round counts and comment totals were not publicly recoverable for these records.

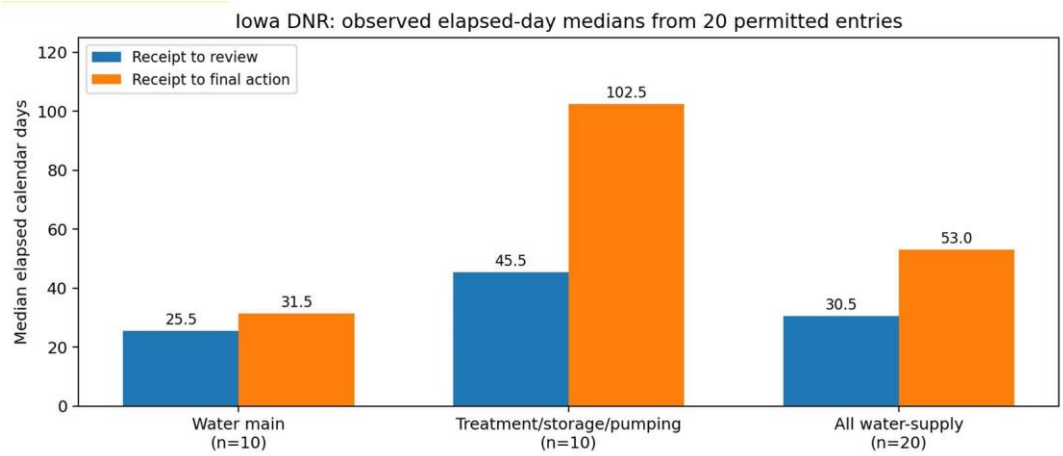


Figure 5: Descriptive elapsed permit intervals in 20 source-linked Iowa water-supply cases, by project category.

Figure 5 compares the two Iowa project categories using receipt-to-review and receipt-to-final-action times. Facility cases exhibit a higher median finalization interval within this small selection. The figure does not demonstrate whether particular design deficiencies, the number of examination cycles or the proposed PRI contributed to elapsed time.

Eight of the 20 Iowa cases required more than 60 days from receipt to final action: 2/10 water mains (20%) and 6/10 treatment/storage/pumping facilities (60%). The univariable logistic model estimated $\beta = 1.792$ for the facility indicator and an OR of 6.00 (95% Wald CI 0.81–44.35; Wald $p = 0.079$; Fisher exact $p = 0.170$). Apparent discrimination was ROC-AUC = 0.708 (10,000-replicate bootstrap 95% CI 0.488–0.899). Leave-one-out predictions from an L2-regularized model yielded ROC-AUC = 0.500 and Brier score = 0.245, indicating that the apparent discrimination did not persist in this internal check.

The fixed facility-versus-water-main alert had sensitivity 75.0% (6/8), specificity 66.7% (8/12), overall agreement 70.0% (14/20) and Cohen's $\kappa = 0.400$ (paired-case bootstrap 95% CI −0.023–0.792). This κ is alert-to-outcome categorical concordance, not the inter-rater reliability of Tucson deficiency coding. The association is imprecise and does not establish a statistically secure difference or any predictive relationship involving PRI scores.

Table 5A: Exploratory Iowa finalization-time association and classification indices (n = 20).

Verified observable or statistic	**Result**	**Interpretation / denominator**
Water-main permits taking >60 days	2/10 (20.0%)	8/10 at or below 60 days
Treatment / storage / pumping >60 days	6/10 (60.0%)	4/10 at or below 60 days
Logistic coefficient, facility indicator	$\beta = 1.792$	Timing outcome only; no PRI predictor

Unadjusted odds ratio; 95% Wald CI	6.00 [0.81, 44.35]	Wald p = 0.079; exact p = 0.170
Apparent ROC-AUC [95% bootstrap]	0.708 [0.488, 0.899]	Same records used for fitting
Leave-one-out ROC-AUC / Brier	0.500 / 0.245	19 train, one test, repeated 20 times
Heuristic-to-outcome Cohen κ	0.400 [−0.023, 0.792]	Not Tucson dual-coder agreement

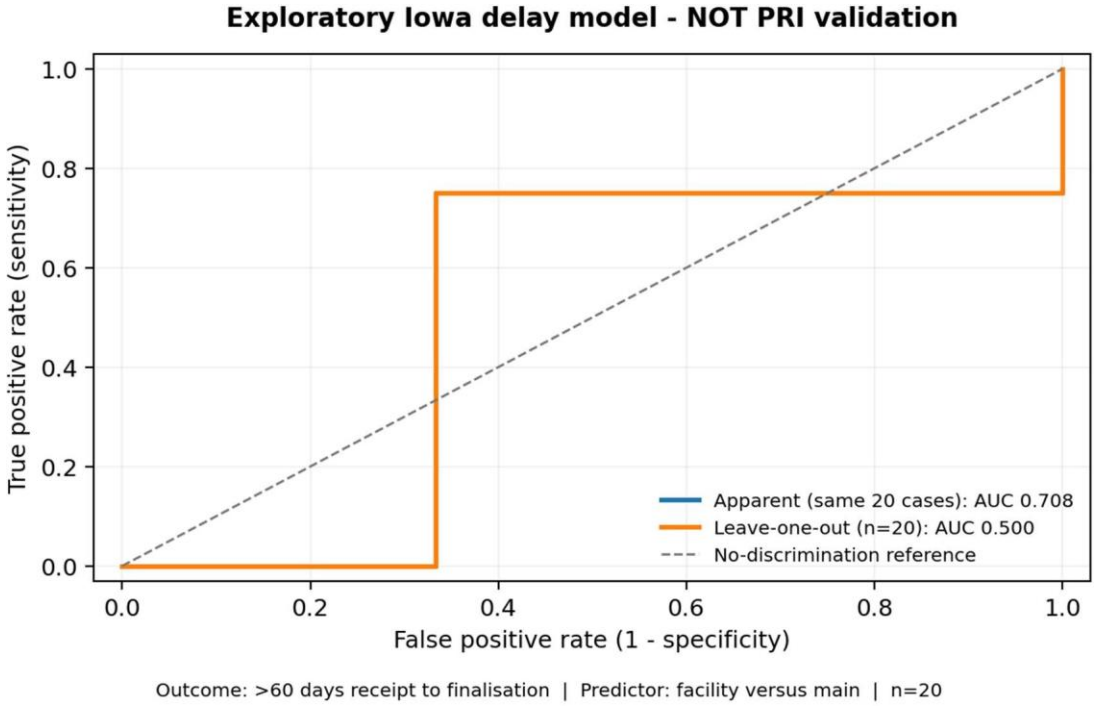


Figure 5A: Apparent and leave-one-out ROC curves for an Iowa project-type model of finalization after 60 calendar days; neither curve evaluates PRI or permit resubmittal.

5.2Principal Drivers of Water and Wastewater Resubmittals

The 20 Tucson comments selected for the coding demonstration were distributed across eight predefined primary classes: easements/external approvals (4; 20%); drawings/document control (3; 15%); hydraulic/design

calculations (3; 15%); technical water/wastewater design (3; 15%); administrative completeness (2; 10%); utility

coordination (2; 10%); standards compliance (2; 10%); and response traceability (1; 5%). Figure 6 presents the corresponding counts and cumulative percentages. Because cases were intentionally selected to illustrate all eight classes, the category order must not be interpreted as a representative Pareto ranking, a population estimate of principal causes, or evidence of an 80/20 pattern. Each observation and primary code is traceable to an official City of Tucson record in Appendix B.

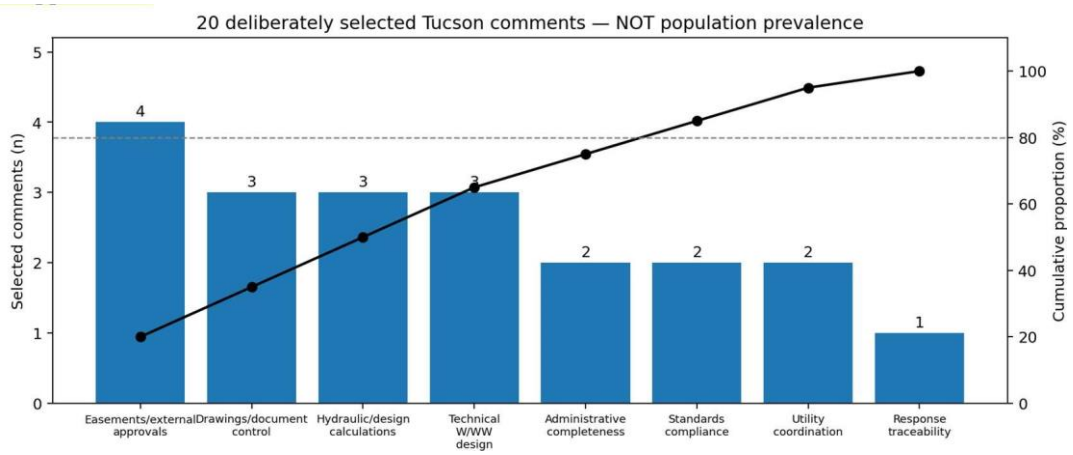


Figure 6: Illustrative coded-category counts and cumulative percentages for 20 purposively selected Tucson correction comments.

5.3Performance of the Permit Readiness Index

The 30-item PRI can be applied to complete design-package evidence using the specified item rules and domain equation. In the two audited sources, however, no application-time engineering package was available that permitted defensible project-level scoring. Consequently, no observed PRI distribution, association between PRI and plan examination, or PRI-specific logistic regression, odds ratio, ROC-AUC, sensitivity, specificity, positive predictive value or negative predictive value can be estimated. Additionally, correction comments were intentionally chosen from the Tucson files, and no clear correlation was established with an unbiased subset of first-cycle approvals. Constructed sensitivity profiles can never replace scored real projects.

The narrower empirical question addressed by the statistical results in Table 5A is whether project category is related to an elapsed-finalization threshold in 20 Iowa water-supply approvals selected for the study. However, the predictor is not a readiness score; the outcome is not resubmittal, but infrastructure type and time to final action. The wide OR confidence interval, null leave-one-out AUC, and lack of a comparator arm for unsuccessful initial submissions preclude conclusions about the PRI's predictive accuracy or the value of avoiding resubmittals.

Submissions for prospective PRI validation should be a series of adjacent or random submission events from the same permit authority and of similar project types. A completed plan and supporting calculations that have been submitted shall be retained in the state in which they were submitted prior to the initial regulatory decision. The date-locked submissions should be independently scored by trained assessors who are blinded to eventual outcomes, and both first-cycle acceptances and required corrections/resubmittals should be represented. Prespecified outcomes should involve the number of times the submissions were made, number of comments, number of additional reviews and elapsed days as well as examiner effort separately recorded; outcomes can be used to aid interrater reliability, calibrated logistic regression and held-out ROC analysis (Fauth, Bloch, Soibelman, & I. Brilakis, 2024).

5.4Integrated Discussion and Practical Implications

The study produces three defensible products: a verifiable subset of the Iowa water-supply population with permit-processing intervals; examples of how the eight deficiency

themes can be coded in Tucson municipal comments; and a fully specified 30-control screening protocol based on authoritative agency requirements. These contributions complement each other and cannot replace the other. Combining these two records would produce an incorrect denominator and would not generate corresponding outcomes to estimate PRI performance; these records are based on different standards of jurisdiction, unit of observation, and approval regime.

The ancillary Iowa model indicates a potential association between project scope and total elapsed permitting time, but the 95% OR interval spans unity, the sample size is small, and leave-one-out ROC-AUC is 0.500. It should not be used for causal inference or as a practical predictive model. Cohen's $\kappa = 0.400$ reflects only the agreement between the project-type alert and the sustained-finalization indicator. Specifically, it provides no information on whether different engineers consistently assign the planned 30 scores for the PRI or the Tucson deficiency codes.

The PRI is an evidence-based pre-submittal quality assurance tool, but it has not yet been evaluated for feasibility or psychometrics. Statutory and utility requirements remain in effect, and internal scoring is not a substitute for requirements imposed by engineering judgment or formal agency decisions. Table 6 categorizes the directly supported finding from the numerical sensitivity exercise and outstanding validation questions.

Table 6: Supported findings, limitations and appropriate uses of the proposed PRI

Aspect	Empirical evidence / instrument status	Practical implication
Iowa time audit	20 public dated permit entries; medians and IQRs computed	Useful for limited process description, not PRI prediction
Tucson coding audit	20 explicit comments show all eight technical/admin classes	Codebook demonstrable; sample not representative
Source comparability	Different jurisdiction, permit regimes and evidence units	No 40-case pooled statistical prediction dataset
Scoring reproducibility	30 checks have explicit 0/1/2, N/A and critical-fail rules	A second engineer can trial the same checklist
Predictive validity	No observed PRI scores or matched approval/resubmit pairs	PRI-specific discrimination and odds ratios remain unestimated
Reliability	No independent duplicate coding of the 20 Tucson comments	κ threshold not tested; cannot report it as passed
Sensitivity	Hypothetical score profiles change with thresholds/weights	Calibrate bands and weights before real deployment

5.5Future Research and Recommendation

Future studies should include all municipal water and wastewater submissions within the same jurisdiction, including first-cycle approvals and correction-resubmittal results. The package should be sealed before the outcome

is known. At least two different assessors should score the 30 checklist items and the plan comments for the examinations so that the percentage item agreement, nominal-category Cohen's κ, and ordinal reliability statistics with uncertainty intervals can be computed transparently (Vanbelle, Engelhart, & E. Blix, 2024). Only after a prespecified analysis plan that estimates first-pass acceptance, comment volume, number of review cycles, calendar duration, and hours of work spent by the examining partners can the odds ratios, calibration, and out-of-sample ROC-AUC be evaluated in relation to PRI.

Sample and analysis should be customized to mirror the infrastructure type, technical complexity, jurisdiction, project valuation, and plan examiner discipline and external approval requirements, while avoiding unintended combinations of incompatible outcome definitions. Investigators should evaluate other weights and thresholds derived from elicitation or empirical calibration, test critical fail-over and override performance, and test generalizability in a holdout sample not used to calculate the weights and thresholds. Any observed decrease in resubmittal rates must be evaluated using a controlled before-and-after/matched-cohort or randomized implementation design and must distinguish between delayed applicant resubmittals and agency processing.

6. Conclusions

Coordinated engineering documentation, defensible calculations, and timely resolution of utility and interagency interfaces are required to obtain municipal water/wastewater permits. These documents represent primary agency guidance for constructing the structured pre-submission assessment, along with example source-linked comments showing the classes of missing and inconsistent comments the assessment addresses. These examples do not indicate the prevalence of a population deficit or the causal impact of each defect; resubmittal is an analytically distinct construct from defects that occur during construction.

An audit of 20 Iowa water-supply permits yielded median receipt-to-review and receipt-to-finalization intervals of 30.5 and 53.0 calendar days. In a separate 20-case Tucson comment audit, eight predefined deficiency types were coded with traceable sources. The exploratory Iowa-only analysis of finalization beyond 60 days gave a treatment/storage/pumping-versus-water-main OR of 6.00 (95% Wald CI 0.81–44.35), an apparent ROC-AUC of 0.708 and leave-one-out ROC-AUC of 0.500. A simple project-type alert showed Cohen's $\kappa = 0.400$ with the timing outcome, which does not represent agreement between independent coding assessors. Exploratory results do not estimate PRI effectiveness, and the study did not combine the two source populations.

The methodological contribution is an explicit, scalable 30-item, six-domain, 100-point Permit Readiness Index with observable 0/1/2 scoring states, justified N/A exclusions, a conditional critical-fail override, and an auditable review and sign-off process. The domain weights and decision boundaries (15, 20, 25, 15, 15, 10, 90, and 80) are screening values that are defined by the authors and are not regulatory thresholds based on data. The four hypothetical projects show that small changes to these parameters can significantly affect the project readiness classification near the edges, indicating a need to calibrate them before use.

The proposed pre-submission quality gate helps get a submission into the system with technical omissions and/or unresolved approvals. However, it has not yet been shown to reduce review time or resubmissions. The next requirement is an outcome cohort within the same jurisdiction with pre-submission dates, first-cycle decisions, and independent duplicate scoring. Until such information is available, candidates should use the PRI as a quality control tool if they are required to assist with municipal permitting, but not as a validated tool to assist with

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Appendix:

Appendix A: Iowa DNR W/WISARD audit

The Iowa audit comprises 20 purposively selected, finalized water-supply construction permits. Each source-linked project number identifies an official W/WISARD page displaying its received, reviewed and finalized dates and final action. R→V denotes elapsed calendar days from receipt to recorded review; R→F denotes receipt to final action. All 20 cases are recorded as "Permitted," by the selection rule. The underlying information is available through Iowa DNR.

Reproducibility files include the 20-row transcription, the calculated date differences, and the binary timing outcome, the out-of-fold predictions at the case level, the logistic-regression script, and the figure data for the bootstrap sampling procedure. There are explicit governmental source URLs in all 20 records. The 60-day finalization cutoff and infrastructure-type indicator were added only to the exploratory association analysis and were not used as a PRI score or a proxy for observed resubmittal.

Project (official link)	Type	Received	Reviewed	Finalized	R→V d	R→F d
W2026-0257	Water main	2026-03-19	2026-05-12	2026-05-14	54	56
W2026-0157	Water main	2026-01-26	2026-02-18	2026-04-10	23	74
W2026-0400	Water main	2026-05-14	2026-06-17	2026-06-18	34	35
W2026-0323	Water main	2026-04-16	2026-05-11	2026-06-05	25	50
W2026-0179	Water main	2026-02-05	2026-03-03	2026-03-03	26	26
W2025-0350	Water main	2025-04-10	2025-05-30	2025-06-12	50	63
W2026-0340	Water main	2026-04-23	2026-05-20	2026-05-20	27	27
W2025-0395	Water main	2025-05-07	2025-05-29	2025-06-04	22	28
Project (official link)	Type	Received	Reviewed	Finalized	R→V d	R→F d
W2026-0219	Water main	2026-03-04	2026-03-09	2026-03-10	5	6
W2026-0039	Water main	2025-10-24	2025-10-27	2025-10-28	3	4
W2025-0527	Other water	2025-08-01	2025-08-28	2025-08-28	27	27
W2023-0514	Other water	2025-03-17	2026-01-22	2026-05-04	311	413
W2025-0236	Other water	2025-12-11	2026-01-29	2026-06-23	49	194
W2022-0675	Other water	2025-01-20	2025-04-07	2025-05-08	77	108
W2025-0073	Other water	2025-04-30	2025-06-30	2025-09-24	61	147

W2026-0085	Other water	2026-05-11	2026-05-20	2026-06-18	9	38
W2026-0112	Other water	2025-12-05	2026-01-16	2026-01-20	42	46
W2022-0722	Other water	2025-10-20	2026-06-29	2026-06-29	252	252
W2023-0599	Other water	2025-08-07	2025-09-16	2025-11-12	40	97
W2025-0579	Other water	2026-02-25	2026-03-04	2026-04-22	7	56

Appendix B: Tucson PRO audit

The Tucson appendix lists 20 different City of Tucson PRO case identifiers and the official public plan-examination detail URLs. A total of one correction statement was paraphrased per case with a primary deficiency code assigned. The classes are deliberately selected to include all eight classes specified, and the tabulated frequencies are intended to illustrate the codebook and verify the sources, rather than to infer the prevalence of defects in the city as a whole.

Permit/plan (official link)	Primary class	Specific plan examiner-observed issue (paraphrase)
TC-COM-0324-00553	Administrative completeness	Undated engineer seal on plumbing submission
TC-COM-0923-02244	Administrative completeness	Incomplete plans lacking Arizona registrant seal
TC-COM-0424-00665	Drawings/document control	Sewer cleanout at conflicting locations across drawings
TC-COM-0524-00906	Drawings/document control	Civil and plumbing floor/invert elevations inconsistent
TC-COM-0924-01761	Drawings/document control	Water-pipe diameter differs on plan and diagram
TC-COM-0425-00651	Hydraulic/design calculations	Proposed water demand for selected meter missing
TC-COM-1224-02387 verification	Hydraulic/design calculations	Water meter/backflow pressure-drop requested
TC-COM-0524-01034 discharge flow	Hydraulic/design calculations	Drain sizing must account for pump
TD-DEV-0324-00073 using revised sewer	Technical water/wastewater design	Backwater valve design needed manhole elevation
TC-COM-0624-01263 requires further	Technical water/wastewater design	Private sewer slope omitted; design engineering review

TD-DIV-1224-00093	Technical water/wastewater design	Independent sewer connection per parcel not demonstrated
TD-DEV-0424-00124	Utility coordination	Existing utility locations sizes and sewer connection not shown
TD-DIV-0425-00056	Utility coordination	Plat lacks utility information and access provisions
TD-DEV-1124-00305	Easements/external approvals	Dimensioned easement/joint sewer use agreement missing
TD-DIV-0624-00055	Easements/external approvals	County wastewater approval letter outstanding
TD-DIV-1124-00088	Easements/external approvals	County wastewater approval letter outstanding
TC-COM-0523-01382	Easements/external approvals	Private sewer needs county environmental approval before city submission
TC-COM-0725-01347	Standards compliance	Water-meter setback/backflow assembly standards
TC-COM-1124-02117	Standards compliance	PVC disallowed for building water distribution by code

Permit/plan (official link)	Primary class	Specific plan examiner-observed issue (paraphrase)
TC-COM-0624-01208	Response traceability	Prior plumbing design correction expressly still not addressed