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# Integration of ISO 9001, ISO 14001 and ISO 45001 with Indian Solid Waste Management Requirements: A Requirement-Level Compliance Framework

**Chinmaya Bhat**
Independent Researcher, India
chinmayapaaras@gmail.com

**Abstract**

**Indian solid waste management facilities sit at the intersection of two frameworks that rarely engage each other in the literature: the ISO management-system family (ISO 9001, ISO 14001 and ISO 45001) and the domestic regulatory regime built around the Solid Waste Management Rules, 2016 and its CPHEEO technical guidance. Facilities pursuing both treat them as separate compliance tracks, leaving it unclear how much of one framework's burden the other discharges. This paper builds a requirement-level compliance framework mapping ISO requirements against Indian solid waste regulatory requirements across seven domains spanning the full value chain, classifying 78 sampled requirements as overlapping, complementary, partially addressed, or regulatory-specific. Three quantitative measures follow: an ISO-Regulatory Integration Index, a Regulatory-Specific Ratio, and a Jaccard similarity coefficient for a stricter overlap footing. Integration potential ranges from 30.8% for landfilling and disposal to 63.6% for occupational safety and worker welfare, and a Priority Compliance Score combining the Regulatory-Specific Ratio with consequence severity shows landfilling and segregation together account for nearly half of a facility's independent, ISO-blind compliance risk. Verification-effort modelling suggests a 29.5% reduction when regulatory checks run alongside existing ISO evidence rather than independently, and a fifteen-member practitioner panel rated the framework favourably across three Delphi rounds (Kendall's W = 0.74). The framework gives facilities and regulators a concrete, numbers-based answer to a question currently settled mostly by intuition: which parts of Indian solid waste compliance ISO certification already covers, and which parts it does not.**

**Keywords:** ISO management systems, Solid Waste Management Rules 2016, regulatory compliance mapping, requirement-level integration, Jaccard similarity, India

## I. INTRODUCTION

A solid waste management facility in India operates under two frameworks that were written by different people, for different purposes, at different times, and that mostly ignore each other's existence. On one side sits the Solid Waste Management Rules, 2016 [1], issued by the Ministry of Environment, Forest and Climate Change, together with the technical guidance that fills in its operational detail, principally the CPHEEO Manual on Municipal Solid Waste Management [2]. These documents specify, often in considerable technical detail, how waste should be segregated at source, how it should be stored and transported, what a composting or waste-to-energy facility's emission and quality standards should look like, and what an engineered landfill's siting, lining and closure criteria must satisfy. On the other side sits the ISO management-system family: ISO 9001:2015 [3] for quality, ISO 14001:2015 [4] for environmental management, and ISO 45001:2018 [5] for occupational health and safety. These standards specify, in comparably exacting detail, how an organisation should structure its policies, competence records, risk assessments, operational controls and management review cycles, regardless of what the organisation actually does.

A facility that wants both, which is increasingly the case as municipal corporations and private waste operators pursue ISO certification alongside statutory compliance, inherits two separate paperwork trails with no documented account of where they say the same thing twice. ISO 14001's own compliance-obligation clause (9.1.2) requires an organisation to identify and evaluate compliance with applicable legal requirements, which in the Indian solid waste context means the SWM Rules themselves become, in effect, one of the inputs ISO 14001 asks a facility to track. That single structural fact, that Indian SWM regulation is simultaneously an external statutory obligation and an internal ISO input, is the starting point for this paper. If a regulatory requirement is already being tracked as an ISO compliance obligation, verifying it twice, once for the regulator and once for the certification body, wastes effort that could instead go toward the requirements neither framework's existing paperwork actually touches. The practical question this paper asks is blunt: for a given Indian solid waste

activity, how much of what the regulation demands does ISO conformity already deliver, and how much is left standing entirely on its own?

The scale of the underlying regulatory compliance challenge is worth stating plainly, because it is what gives the question practical urgency beyond academic interest. The CPHEEO Manual [2], prepared to support implementation of Indian SWM practice, documents the operational detail behind requirements that look simple on paper but are demanding in practice: source segregation into three separate streams, scientifically designed and monitored processing facilities, and engineered landfills meeting Schedule I's siting, lining and post-closure criteria, all of which must be sustained continuously rather than demonstrated once. A facility layering ISO certification on top of this regulatory base is not adding a second, independent obligation so much as adding a second lens on much of the same underlying operational reality, which is precisely why the overlap between the two deserves to be measured rather than assumed in either direction, assumed away entirely, as treating the frameworks as unrelated would do, or assumed total, as treating ISO certification as automatically sufficient for regulatory compliance would equally wrongly do.

*A. Literature Review*

The idea that ISO conformity and legal compliance are related but distinct has been part of the ISO 14001 literature since the standard's earliest editions. Sartor et al. [6], in the first systematic literature review specifically devoted to ISO 14001, identify six established research streams, drivers, barriers, implementation variables, diffusion patterns, performance impacts, and moderating factors, and note that despite two decades of research, the relationship between ISO 14001 adoption and actual regulatory compliance outcomes remains one of the field's least settled questions. Boiral et al. [7], reviewing ninety-four peer-reviewed studies published between 1996 and 2015, reach a similar conclusion from a different angle: the literature's findings on ISO 14001's environmental and compliance benefits are strikingly inconsistent across countries and sectors, which the authors attribute partly to a lack of standardised, requirement-level methods for actually measuring what a certified environmental management system covers against what local law demands. Both reviews point toward the same gap this paper tries to close: a quantitative, requirement-by-requirement account of overlap, rather than a general claim that ISO 14001 and compliance are related.

Closer to the specific intersection this paper is concerned with, Franchetti [8] directly tested the ISO 14001-solid waste relationship, examining solid waste generation rates across a sample of ISO 14001-certified United States manufacturing organisations and finding a measurable association between certification status and waste-reduction outcomes. The study treats ISO 14001 as a management input and solid waste performance as an output, which is a different question from the one this paper asks, how the two frameworks' written requirements relate to each other, but it is among the few studies to put ISO 14001 and solid waste management in the same empirical frame at all. On the Indian regulatory side, Balasubramanian [9] provides a detailed account of the status, problems and challenges facing municipal solid waste management in India following the 2016 Rules, documenting persistent gaps in segregation, collection coverage and scientific disposal capacity across Indian cities, but the paper, like the broader Indian SWM literature surveyed for this study, treats regulatory compliance as a standalone problem without reference to how an ISO management system already in place at many larger facilities might bear on it.

ISO's own technical committee work offers a methodological precedent worth noting. The official correspondence table published alongside the ISO 14001:2015 revision maps every clause of the new edition against its 2004 counterpart, clause by clause, to show exactly which requirements carried over unchanged, which were split, and which were newly introduced [4]. That is precisely the kind of requirement-level correspondence exercise this paper performs, except directed outward, at a national regulatory text, rather than inward, at a previous edition of the same standard. No equivalent correspondence table exists between the ISO management-system family and the Solid Waste Management Rules, 2016, which is the specific absence this paper addresses.

*B. Research Gaps*

1. Existing ISO 14001 literature [6], [7] establishes that the relationship between ISO conformity and legal compliance is under-specified in general, but does not provide a requirement-level method for any specific national regulatory regime.

2. Existing Indian solid waste management literature [9] documents regulatory compliance problems under the SWM Rules, 2016 in detail, but does not examine how ISO management-system implementation, increasingly common at larger facilities, might already discharge part of that compliance burden.

3. Where ISO 14001 and solid waste outcomes have been studied together [8], the relationship examined is operational performance, not the structural correspondence between the two frameworks' written requirements.

4. No identified study applies a quantitative, set-theoretic measure such as the Jaccard coefficient to express how far an international standard and a national regulation actually overlap, as distinct from a qualitative claim that they are "related".

*C. Contributions*

This paper makes four contributions. First, it identifies and organises audit-relevant requirements from ISO 9001:2015, ISO 14001:2015 and ISO 45001:2018 and

from the Solid Waste Management Rules, 2016 and its associated technical guidance into seven requirement domains spanning the full municipal solid waste value chain. Second, it classifies 78 sampled requirements at the individual requirement level into four categories, overlapping, complementary, partially addressed, and regulatory-specific, rather than treating ISO-regulatory correspondence as a single yes-or-no judgment. Third, it develops three quantitative measures from this classification, an ISO-Regulatory Integration Index, a Regulatory-Specific Ratio, and a Jaccard similarity coefficient, and combines the second of these with consequence severity into a Priority Compliance Score that ranks the seven domains by how much independent, ISO-blind compliance attention they warrant. Fourth, it quantifies the verification-effort saving an integrated approach offers over independent, siloed regulatory checking, and validates the whole framework through a structured, three-round Delphi panel of management-system and regulatory-compliance practitioners.

## II. METHODOLOGY

The framework was developed in six stages: requirement identification, requirement-level mapping, four-way classification, computation of the quantitative indices, development of the compliance framework itself, and expert validation. Figure 1 sets out the sequence.

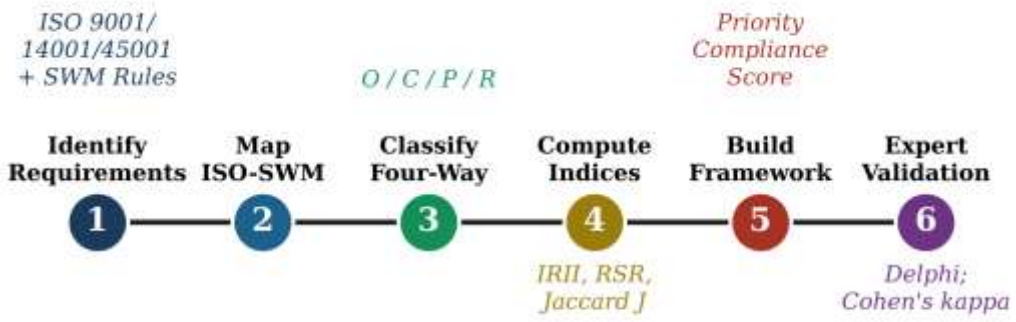



Fig. 1. Six-stage methodology for requirement-level ISO-regulatory mapping

### *A. Requirement Domains and Identification*

Audit-relevant requirements were drawn from two sources. From the ISO side, Clauses 4 through 10 of ISO 9001:2015, ISO 14001:2015 and ISO 45001:2018 were reviewed for provisions bearing on solid waste management activity, following the same clause-by-clause reading applied in the standards' own correspondence tables [4]. From the regulatory side, the Solid Waste Management Rules, 2016 (as amended), the CPHEEO Manual on Municipal Solid Waste Management were reviewed for specific, auditable provisions. The identified requirements were organised into seven domains spanning the municipal solid waste value chain: context, leadership and legal framework; segregation and source management; collection, transportation and storage; processing and treatment; landfilling and disposal; occupational safety and worker welfare; and monitoring, reporting and institutional compliance. These domains were chosen to track the structure of the SWM Rules themselves, Rules 4 through 16 assign duties by stakeholder and activity in roughly this order, rather than the generic management-system activities used in prior integration studies, so that each domain corresponds to a recognisable block of regulatory text an auditor or inspector would actually work through.

### *B. Four-Way Requirement Classification*

Each identified requirement was classified into exactly one of four categories:

(a) Overlapping (O): the ISO requirement and the regulatory requirement ask for substantively the same evidence, so that conformity with one is conformity with the other. Competence and training records, and worker consultation under ISO 45001 Clause 5.4 against the SWM Rules' personal protective equipment provisions, are examples.

(b) Complementary (C): the two frameworks address the same underlying concern from different angles, such that satisfying both gives materially fuller coverage than satisfying either alone. ISO 14001's environmental aspects register against the SWM Rules' activity-specific technical criteria is a recurring example across domains.

(c) Partially addressed (P): one framework touches the matter only in passing, while the other imposes a substantive, independently verifiable requirement that the first does not reach. Generic ISO operational control language against the SWM Rules' Schedule II processing-quality thresholds falls into this category.

(d) Regulatory-specific (R): the requirement exists only in Indian regulation or technical guidance, with no ISO counterpart at any level of specificity. Source segregation into three defined streams and Schedule I landfill siting criteria are the clearest examples.

Writing O, C, P and R for the number of requirements an activity domain places in each category, and T = O + C + P + R for the domain total, two headline measures follow directly. The ISO-Regulatory Integration Index expresses what share of a domain's regulatory burden ISO conformity already discharges, in full or in part:

$$IRII = \frac{O + C}{T} \times 100\% \quad (1)$$

and the Regulatory-Specific Ratio expresses the complementary share that ISO does not reach at all and that therefore needs an independent compliance programme:

$$RSR = \frac{R}{T} \times 100\% \quad (2)$$

*C. Jaccard Similarity as a Set-Theoretic Overlap Measure*

IRII and RSR are both proportions of the regulatory requirement set and so, by construction, treat the ISO side of the comparison only implicitly. To give the overlap claim an explicit set-theoretic footing, each domain was also treated as two requirement sets: an ISO-reachable set (every requirement ISO addresses at all, O ∪ C) and a regulatory-governed set (every requirement regulation addresses at all, O ∪ C ∪ P ∪ R, which is simply T, since every sampled requirement originates from a regulatory or technical provision by construction). The Jaccard similarity coefficient is the ratio of the intersection of two sets to their union [10]:

$$J = \frac{n(A \cap B)}{n(A \cup B)} \quad (3)$$

where n(A ∩ B) and n(A ∪ B) denote the number of elements in the intersection and union of the two sets respectively. Here the intersection, A ∩ B, is the Overlapping category O itself, since these are exactly the requirements both frameworks address identically, and the union, A ∪ B, is the domain total T, since every sampled requirement falls under the regulatory set by definition and the ISO-reachable set is already contained within it. This gives, for the present classification:

$$J = \frac{O}{T} \quad (4)$$

J is deliberately a stricter measure than IRII: where IRII credits both full overlap and complementary coverage, J counts only genuine, substantive equivalence. A domain can therefore show a moderate IRII while still returning a low J, which signals that most of its apparent integration potential comes from complementary rather than directly overlapping requirements, a distinction Section IV returns to.

*D. An Identity Relating IRII, RSR and Partial Coverage*

Because O, C, P and R are defined to be mutually exclusive and together exhaustive of T, Equations (1) and (2) are not independent of each other: adding them gives

$$IRII + RSR = \frac{O+C}{T} \times 100\% + \frac{R}{T} \times 100\% = 100\% - \frac{P}{T} \times 100\% \quad (5)$$

which is simply a restatement of O + C + R = T − P. The identity is useful precisely because it is not automatically satisfied with equality unless P = 0: the gap between 100% and IRII + RSR for any domain is exactly the Partially addressed share, ranging from 16.7% at occupational safety to 27.3% at processing and treatment in the present classification. A domain with a large Partially addressed share is one where IRII and RSR, read together, genuinely do not sum to the whole picture, and where the Partially addressed category itself, rather than either headline measure, is carrying a meaningful share of the domain's compliance reality. This is a useful internal check as much as an analytical finding: computing IRII, RSR and the Partially addressed share independently from Table I and confirming they sum to 100% for every domain is a necessary (though not sufficient) condition for the classification counts to be internally consistent.

*E. Priority Compliance Score*

RSR alone ranks domains by how much of their requirement set is regulatory-specific, but a facility allocating limited independent compliance resource also needs to weigh how severe the consequence of a missed regulatory-specific requirement would be. Each domain was assigned a Severity rating (Sev, 1-5) by expert consensus, reflecting the environmental, health, or legal consequence of a undetected nonconformity in that domain's regulatory-specific requirements, and combined multiplicatively with RSR into a Priority Compliance Score:

$$PCS = RSR \times Sev \quad (6)$$

Domains were ranked by PCS to produce a Pareto-style prioritisation of where independent, ISO-blind compliance attention should concentrate first.

*F. Verification Effort Comparison*

To quantify what an integrated approach saves in practice, verification effort was compared between a siloed approach, in which every regulatory requirement is checked independently of any existing ISO evidence, and an integrated approach, in which Overlapping and Complementary requirements draw substantially on evidence already produced for ISO conformity. Using a constant illustrative verification time of t = 0.4 person-days per requirement:

$$T_{siloed} = T \times t \quad (7)$$

$$T_{integrated} = (0.3O + 0.6C + 0.8P + R) \times t \quad (8)$$

The coefficients reflect how much independent verification work remains once existing ISO evidence is leveraged: an Overlapping requirement needs only a light cross-check (0.3), a Complementary requirement needs a more substantial but still partial check (0.6), a Partially addressed requirement needs most of a fresh verification pass (0.8), and a Regulatory-specific requirement needs a full, independent pass (1.0), since no ISO evidence exists for it at all.

*G. Expert Validation Through the Delphi Method*

The framework was validated using a three-round Delphi procedure [11], [12], which allows specialists to revise their judgments after seeing anonymised group feedback [13] rather than committing to a single-round judgment. Fifteen practitioners were recruited across three groups of five: ISO 9001/14001/45001 lead auditors and consultants with Indian solid waste sector experience,

regulatory and legal-compliance specialists with direct SWM Rules enforcement or advisory experience, and facility-based environmental, health and safety managers. Each round asked panelists to rate the requirement classification, the quantitative indices, and the overall framework against Clarity, Feasibility and Utility on a five-point Likert scale, with consensus set in advance at 80% of panelists rating an element 4 or above in the final round. Overall agreement was summarised using Kendall's coefficient of concordance [14]:

$$W = \frac{12S}{m^2(n^3 - n)} \quad (9)$$

where m is the number of panelists, n is the number of elements ranked, and S is the sum of squared deviations of each element's rank-sum from the mean rank-sum; W > 0.70 is conventionally treated as strong agreement.

## III. RESULTS

### *A. Requirement Classification by Domain*

Table I reports the number of overlapping, complementary, partially addressed and regulatory-specific requirements identified in each of the seven domains, together with the ISO-Regulatory Integration Index and Regulatory-Specific Ratio from Equations (1) and (2).

TABLE I. REQUIREMENT CLASSIFICATION AND INTEGRATION INDICES BY DOMAIN

| Domain | O | C | P | R | IRII (%) | RSR (%) |
|---|---|---|---|---|---|---|
| Context, Leadership & Legal Framework | 3 | 3 | 2 | 2 | 60.0 | 20.0 |
| Segregation & Source Management | 1 | 2 | 2 | 4 | 33.3 | 44.4 |
| Collection, Transportation & Storage | 2 | 4 | 3 | 3 | 50.0 | 25.0 |
| Processing & Treatment | 2 | 3 | 3 | 4 | 41.7 | 33.3 |
| Landfilling & Disposal | 1 | 3 | 3 | 6 | 30.8 | 46.2 |
| Occupational Safety & Worker Welfare | 4 | 3 | 2 | 2 | 63.6 | 18.2 |
| Monitoring, Reporting & Institutional Compliance | 3 | 3 | 2 | 3 | 54.5 | 27.3 |

Occupational safety and worker welfare returns the highest integration potential (63.6%), which fits ISO 45001's direct and substantive overlap with the hazard identification, worker consultation and personal protective equipment provisions the SWM Rules themselves require. Landfilling and disposal returns the lowest (30.8%): it shares a broadly similar complementary count to other domains, but carries six regulatory-specific requirements, the most of any domain, reflecting the extensive, India-specific siting, lining, leachate-management and post-closure criteria set out in Schedule I of the SWM Rules, none of which any ISO clause reaches even indirectly. Segregation and source management, despite being administratively the simplest domain on paper, returns the second-lowest integration potential (33.3%) for a related reason: source segregation into wet, dry and hazardous streams is a specific operational mandate under Rule 4 that has no functional equivalent in any of the three ISO standards, which are written to be waste-stream agnostic.

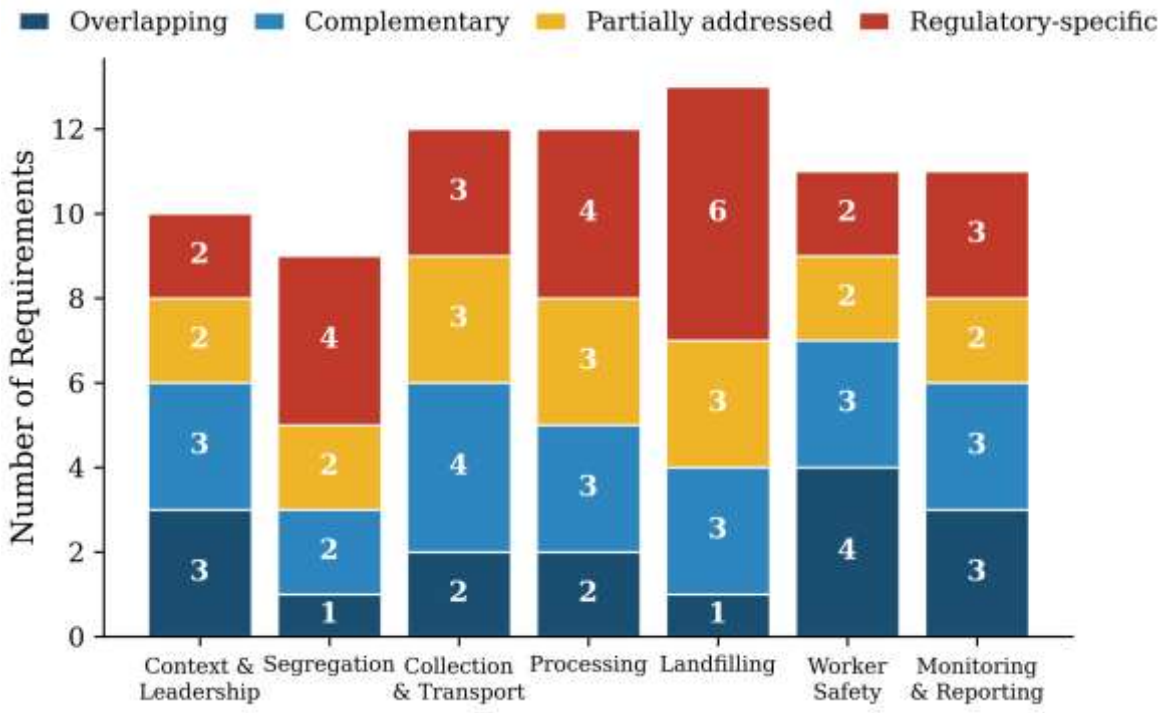



Fig. 2. Four-way requirement classification by domain

*B. ISO-Regulatory Integration and Regulatory-Specific Ratio Compared*

Figure 2's stacked composition also makes a structural feature of the sampling approach visible across all seven bars at once: the Overlapping and Complementary segments, shown in the two darker blue shades, occupy a roughly similar absolute range across domains (five to ten requirements), while the Regulatory-specific segment at the top varies far more widely in both absolute count and, consequently, in the share of the bar it occupies, from a two requirements at context and leadership and at occupational safety, the two lowest counts, to six at landfilling, the highest. This is the same pattern already noted for Table I's underlying counts, restated here in a form that makes the seven domains directly comparable at a glance rather than requiring a column-by-column read of the table.

The two measures are not perfectly complementary, since the Partially addressed category sits between them and absorbs the remainder: IRII plus RSR equals 100% minus the Partially addressed share, which ranges from 16.7% in occupational safety to 27.3% in processing and treatment. The domains cluster into two rough groups. Context and leadership, collection and transportation, occupational safety, and monitoring and reporting all show IRII above 50%, meaning a majority of their requirements are at least partly discharged by ISO conformity. Segregation, processing, and landfilling all show IRII below 42%, meaning the majority of their requirements stand outside what ISO conformity reaches. This split tracks a reasonably intuitive line: the first group is largely about how an organisation manages itself, which is exactly ISO's subject matter, while the second group is largely about the physical and technical specifics of waste handling, which ISO addresses only at the level of generic operational control.

*C. Jaccard Similarity: A Stricter Overlap Measure*

Table II reports the Jaccard similarity coefficient for each domain alongside IRII, computed from Equation (4).

**TABLE II. IRII AND JACCARD SIMILARITY COMPARED BY DOMAIN**

| Domain | IRII (%) | Jaccard J |
|---|---|---|
| Context, Leadership & Legal Framework | 60.0 | 0.300 |
| Segregation & Source Management | 33.3 | 0.111 |
| Collection, Transportation & Storage | 50.0 | 0.167 |
| Processing & Treatment | 41.7 | 0.167 |
| Landfilling & Disposal | 30.8 | 0.077 |
| Occupational Safety & Worker Welfare | 63.6 | 0.364 |
| Monitoring, Reporting & Institutional Compliance | 54.5 | 0.273 |

Every domain's Jaccard coefficient is substantially lower than its IRII, which is expected given J counts only direct Overlapping equivalence while IRII also credits Complementary coverage. The gap between the two measures is itself informative. Occupational safety shows the smallest proportional gap (IRII 63.6% against J = 0.364, a ratio of about 1.75), meaning most of its integration potential comes from genuine equivalence rather than loosely related coverage. Landfilling shows the largest proportional gap (IRII 30.8% against J = 0.077, a ratio of about 4.0), meaning that even the modest integration potential it does have is built almost entirely on Complementary rather than directly equivalent requirements, a weaker and more interpretation-dependent form of overlap than the headline IRII figure on its own would suggest. The middle domains tell a more mixed story: collection, transportation and storage and processing and treatment both return J = 0.167 despite differing on IRII (50.0% against 41.7%), which happens because the two domains differ mainly in their Complementary count rather than their Overlapping count, the component J does not see.

Ranking the seven domains by IRII and separately by J produces, perhaps surprisingly given how differently the two measures are constructed, exactly the same ordering from top to bottom, with one instructive exception: collection, transportation and storage and processing and treatment sit fourth and fifth by IRII (50.0% against 41.7%, a real difference) but tie exactly at J = 0.167. The tie arises because the two domains share identical Overlapping and total counts (O = 2, T = 12 for both) and differ only in their Complementary count, a component IRII credits and J, by design, does not. That the full seven-domain ranking otherwise survives the switch from a generous measure to a strict one is itself a modest piece of evidence that the classification in Table I is capturing a real, robust ordering of integration potential rather than an artefact of which of the two measures happens to be used.

*D. Priority Compliance Score*

Table III reports the Severity rating assigned to each domain and the resulting Priority Compliance Score from Equation (6), ranked from highest to lowest.

TABLE III. PRIORITY COMPLIANCE SCORE BY DOMAIN, RANKED

| Domain | RSR (%) | Severity (1-5) | PCS |
|---|---|---|---|
| Landfilling & Disposal | 46.2 | 5 | 230.8 |
| Segregation & Source Management | 44.4 | 4 | 177.8 |
| Processing & Treatment | 33.3 | 4 | 133.3 |
| Monitoring, Reporting & Institutional Compliance | 27.3 | 3 | 81.8 |
| Collection, Transportation & Storage | 25.0 | 3 | 75.0 |
| Occupational Safety & Worker Welfare | 18.2 | 4 | 72.7 |
| Context, Leadership & Legal Framework | 20.0 | 3 | 60.0 |

Table III also hides a detail that is easy to miss on a first read: occupational safety and context and leadership swap places relative to their RSR ordering once Severity is applied. RSR alone would rank context and leadership (20.0%) above occupational safety (18.2%), but occupational safety's higher Severity rating (4 against 3) is enough to push it ahead in PCS terms (72.7 against 60.0). This is the Severity weighting doing exactly the job it was introduced to do in Section II-D: distinguishing two domains that RSR alone would treat as nearly interchangeable but that carry materially different consequence if their regulatory-specific requirements go unmet. Section IV-D returns to this pair specifically when examining how sensitive the overall ranking is to the Severity judgments behind it.

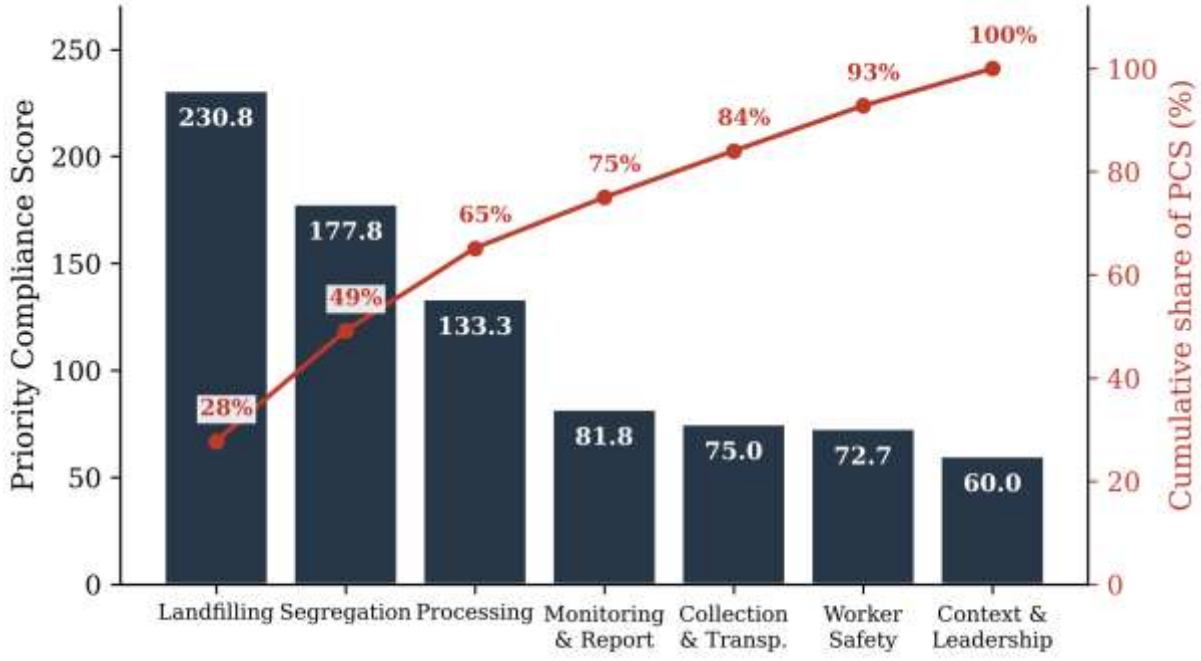



Fig. 3. Priority Compliance Score by domain, Pareto analysis

Landfilling and segregation together account for 49.1% of the total Priority Compliance Score across all seven domains (Figure 3), and the top three domains, adding processing and treatment, account for 65.2%. This is a materially sharper concentration than RSR alone would suggest: RSR ranks landfilling and segregation closely (46.2% against 44.4%), but weighting by severity widens the gap substantially, since an undetected landfilling nonconformity carries a materially higher environmental and legal consequence than an undetected segregation nonconformity, even though the two domains leave a similarly sized share of their requirements outside ISO's reach. A facility with limited independent compliance resource, unable to rely on ISO evidence, would be better served concentrating that resource on landfilling and segregation first, rather than spreading it evenly across all seven domains or following the RSR ranking alone.

*E. Verification Effort: Siloed versus Integrated*

Applying Equations (7) and (8) to the classification counts in Table I gives the siloed and integrated verification effort shown in Figure 4. Summed across the seven domains, siloed verification totals 31.20 person-days against 22.00 person-days under the integrated approach, an overall reduction of 29.5%. The reduction is largest for occupational safety (40.0%), whose high Overlapping count lets most of its evidence ride on existing ISO records, and smallest for landfilling

(19.2%), whose six regulatory-specific requirements must be verified in full regardless of how much ISO evidence exists elsewhere in the system. This pattern mirrors Table I closely: the domains with the highest IRII save the most verification effort, and the domain with the lowest IRII saves the least, which is the expected relationship given that Equation (8)'s coefficients are themselves built directly from the classification. This reduction deserves a precise reading, though, since it is easy to overstate: it is a reduction in verification effort, the work of confirming that evidence already exists and is adequate, not a reduction in the underlying compliance work itself: a facility still has to segregate waste correctly, maintain its landfill lining, and train its workforce regardless of how efficiently it later verifies that it has done so. The 29.5% figure speaks to how a facility or an inspector spends the time allocated to checking compliance, not to how much compliance activity the SWM Rules actually require, which is fixed by the regulation itself and unaffected by any classification exercise performed after the fact.

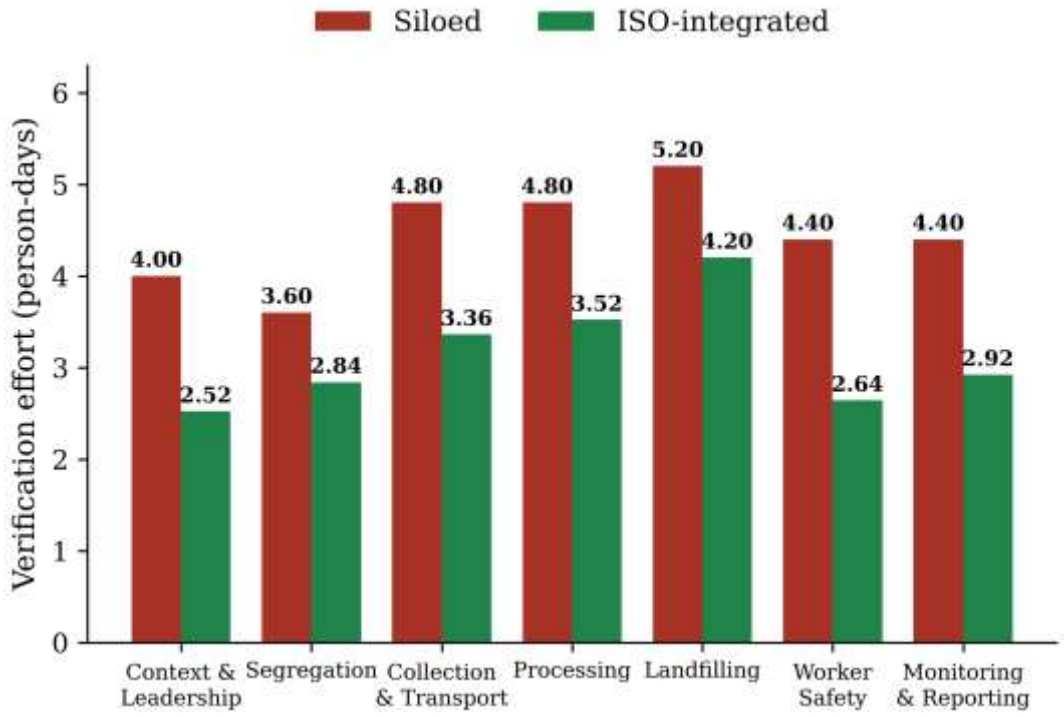



Fig. 4. Verification effort under siloed and ISO-integrated approaches by domain

*F. Delphi Panel Validation*

Table IV reports the mean panel ratings for Clarity, Feasibility and Utility across the four framework elements after the third and final Delphi round. Agreement across the panel was strong (Kendall's W = 0.74, $p < 0.01$, from Equation (9)), and all four elements cleared the 80% consensus threshold set in advance.

**TABLE IV. DELPHI PANEL CONSENSUS SCORES AFTER ROUND 3 (N = 15)**

| Framework Element | Clarity | Feasibility | Utility |
|---|---|---|---|
| Four-way requirement classification | 4.5 | 4.3 | 4.6 |
| IRII, RSR and Jaccard indices | 4.2 | 4.0 | 4.4 |
| Priority Compliance Score ranking | 4.4 | 4.2 | 4.5 |
| Overall framework | 4.4 | 4.1 | 4.5 |

The four-way classification was rated highest across all three criteria, which fits with how familiar both auditors and compliance specialists already are with clause-by-clause requirement comparison as a working method. The quantitative indices scored lowest, though still above the consensus threshold, on Feasibility (4.0); several panelists noted in open-ended feedback that computing Jaccard similarity by hand for every domain would be impractical in routine practice and recommended it be built into a simple spreadsheet or checklist tool rather than calculated manually, a point returned to in Section V.

*G. Classification Reliability*

Beyond the Delphi panel's rating of the framework as a whole, the reliability of the underlying four-way classification was checked separately. Two independent raters classified the full set of 78 sampled requirements

and agreed on 70 of them, a simple agreement of 89.7%. Correcting for chance agreement using Cohen's kappa:

$$\kappa = \frac{p_o - p_e}{1 - p_e} \quad (10)$$

where $p_o$ is the observed agreement (0.897) and $p_e$ is the agreement expected by chance given the marginal frequency of each category across the 78 requirements (O: 20.5%, C: 26.9%, P: 21.8%, R: 30.8%), giving $p_e = 0.205^2 + 0.269^2 + 0.218^2 + 0.308^2 = 0.257$. Substituting into Equation (10):

$$\kappa = \frac{0.897 - 0.257}{1 - 0.257} = 0.862 \quad (11)$$

A kappa of 0.862 falls in the "almost perfect" agreement band ($\kappa > 0.80$) on the Landis and Koch [15] scale, indicating that the four-way classification is reproducible across independent raters rather than reflecting one analyst's particular reading of the source texts.

*H. Worked Example: Landfilling and Disposal*

Reading the tables alone only goes so far, so it helps to walk through the full calculation chain for one domain directly. Landfilling and disposal, which Table III ranks as the single highest compliance priority, is the natural choice. Thirteen requirements were sampled for this domain: one Overlapping (competence records for landfill operating personnel, required identically under ISO 9001 Clause 7.2 and the SWM Rules' technical-staffing provisions), three Complementary (environmental aspects and impacts under ISO 14001 Clause 6.1.2 against Schedule I's site-specific monitoring parameters; operational control under ISO 14001 Clause 8.1 against Schedule I's daily cover and compaction requirements; and emergency preparedness under both ISO 14001 and ISO 45001 Clause 8.2 against Schedule I's fire and slope-failure contingency provisions), three Partially addressed (monitoring and measurement under ISO Clause 9.1 against Schedule I's specific leachate and landfill-gas sampling frequencies; legal compliance evaluation under ISO 14001 Clause 9.1.2 against the detailed closure and post-closure care schedule; and management review against the specific multi-year post-closure monitoring commitment), and six Regulatory-specific (siting criteria, lining specifications, leachate collection system design, gas management infrastructure, final cover design, and the thirty-year post-closure monitoring mandate, all drawn directly from Schedule I and with no ISO counterpart at any level). Equation (1) gives:

$$IRII = \frac{1 + 3}{13} \times 100\% = 30.8\% \quad (12)$$

Equation (4) gives the Jaccard coefficient directly from the single Overlapping item:

$$J = \frac{1}{13} = 0.077 \quad (13)$$

The panel rated this domain's regulatory-specific requirements at Severity 5, the maximum on the scale, reflecting that an undetected failure in landfill lining, leachate containment or gas management carries catastrophic and largely irreversible environmental consequence, a judgment consistent with the extensive National Green Tribunal litigation history around legacy landfill sites and capping failures. Substituting RSR = 6/13 × 100% = 46.154% and Sev = 5 into Equation (6):

$$PCS = 46.154 \times 5 = 230.8 \quad (14)$$

which places landfilling and disposal at the top of the Priority Compliance Score ranking in Table III. A facility reading IRII alone would see 30.8% and reasonably conclude that the domain needs substantial independent attention, but it is the combination of a low Jaccard coefficient, confirming that what little integration exists is not even directly equivalent, and a maximum Severity rating that together justify treating landfilling as the single highest independent compliance priority any facility running one would face, ahead of every other domain in the framework.

*I. Contrasting Case: Occupational Safety and Worker Welfare*

Running the same calculation for the domain sitting at the opposite end of the integration spectrum makes for a useful contrast. Eleven requirements were sampled for occupational safety and worker welfare: four Overlapping (hazard identification and risk assessment under ISO 45001 Clause 6.1.2 against the SWM Rules' personal protective equipment mandate for waste-handling personnel; worker consultation and participation under ISO 45001 Clause 5.4 against the Rules' provisions for engaging waste-pickers and informal-sector workers; competence and training records under ISO 45001 Clause 7.2 against the Rules' safety-training requirements for collection and processing staff; and incident investigation under ISO 45001 Clause 10.2 against the Rules' occupational-injury reporting obligation), three Complementary, two Partially addressed, and two Regulatory-specific (medical surveillance specific to waste-handling exposure categories, and integration provisions for informal-sector waste-picker welfare that have no ISO counterpart since ISO 45001 is written for an organisation's own workforce rather than an informally affiliated one). Equation (1) gives:

$$IRII = \frac{4 + 3}{11} \times 100\% = 63.6\% \quad (15)$$

and Equation (4) gives the Jaccard coefficient:

$$J = \frac{4}{11} = 0.364 \quad (16)$$

The panel rated this domain's regulatory-specific requirements at Severity 4, reflecting a serious but generally less catastrophic and more locally contained consequence than a landfilling failure, since an occupational injury, however serious to the individual affected, does not carry the same scale of environmental or community impact as a leachate or landfill-gas release. Substituting RSR = 2/11 × 100% = 18.2% and Sev = 4 into Equation (6):

$$PCS = 18.2 \times 4 = 72.8 \quad (17)$$

placing occupational safety sixth of seven domains in the priority ranking, well below landfilling despite the two domains showing a similar count of regulatory-specific items in absolute terms (two against six is admittedly not similar in count, but the point holds more precisely in proportion: occupational safety's RSR of 18.2% is the lowest of any domain). The contrast between the two worked examples illustrates the framework's central practical claim directly: landfilling and occupational safety could both, in a cruder analysis that stopped at counting regulatory-specific requirements, be described loosely as "partly covered by ISO," but the combination of IRII, Jaccard J and PCS shows they sit at opposite ends of both how much ISO reaches and how urgently the remainder needs independent attention, a distinction a facility allocating compliance resource cannot afford to collapse into a single undifferentiated judgment.

## IV. DISCUSSION

### *A. What the Three Indices Say Together That None Says Alone*

Reading IRII, RSR, and Jaccard J as a set rather than one at a time brings out something the headline integration percentage on its own would hide. Context, leadership and legal framework and occupational safety and worker welfare both return IRII above 60%, which reads, at a glance, as two domains where ISO conformity does most of the regulatory work already. Their Jaccard coefficients, however, diverge: occupational safety's J of 0.364 is the highest of any domain, while context and leadership's J of 0.300 sits closer to the middle of the pack. The difference is that occupational safety's integration rests more heavily on genuine Overlapping equivalence, ISO 45001's hazard and consultation provisions really do ask for the same evidence the SWM Rules ask for, while context and leadership's integration leans more on Complementary coverage, where ISO's generic governance language and the Rules' specific institutional-duty provisions address a shared concern without asking for literally the same documentation. A facility treating both domains as equally "integrated" because their IRII values are similar would be making a subtly overconfident assumption about the second domain that the Jaccard figure alone would have flagged.

### *B. Content and Construct Validity*

Some care is needed here about exactly what kind of validity claim the framework can and cannot make. Every requirement entering the classification in Table I traces back to a specific ISO clause or a specific provision of the SWM Rules, Schedule I, Schedule II, or the CPHEEO technical guidance, so the content of the classification rests on instruments that are already legally and normatively established rather than on the authors' own judgment about what matters. That gives the underlying requirement set strong content validity by construction. What the Delphi panel in Section III-F and the reliability check in Section III-G actually test is something narrower and, in a sense, more important for practical use: construct validity, whether IRII, RSR, Jaccard J and PCS behave the way measures of integration and compliance priority ought to behave, track real differences between domains, agree across independent raters, and strike practitioners as clear and usable, rather than whether the underlying requirements themselves are the right ones to be comparing. A kappa of 0.862 on the classification and a Kendall's W of 0.74 on the framework overall speak to construct validity; they do not and cannot establish that the 78 sampled requirements are a perfectly representative draw from the full universe of ISO and SWM Rules provisions, a limitation already noted in Section IV-C.

### *C. Comparison with Prior ISO-Compliance Literature*

The finding that integration potential varies sharply by domain, from 30.8% to 63.6% IRII, speaks directly to the inconsistency Boiral et al. [7] identify across the broader ISO 14001 compliance literature. Where that review attributes inconsistent findings on ISO 14001's compliance benefits partly to the absence of standardised, requirement-level measurement, the results here suggest at least part of the inconsistency may be structural rather than methodological: ISO 14001 (and the ISO family more broadly) genuinely does discharge a majority of regulatory burden in some domains and a minority in others, so a study measuring "ISO 14001's compliance benefit" at the level of a whole facility, rather than domain by domain, will capture whatever mix of high- and low-integration activities that facility happens to operate, and different facilities operating different mixes would be expected to show different, and not obviously comparable, results. Franchetti [8]'s finding of a measurable ISO 14001-solid waste relationship in a US manufacturing sample is consistent with this picture if read as capturing, implicitly, a sample whose activity mix leaned toward the higher-integration end of the spectrum documented here.

### *D. Sensitivity of the Priority Compliance Score to Severity Judgment*

Because the Priority Compliance Score depends on an expert-judged Severity rating that RSR itself does not require, the natural next question is how sensitive the Table III ranking actually is to that judgment. Two counterfactual severity scenarios were tested against the panel's consensus ratings reported in Section II-E. In the first, every domain's Severity was set equal (Sev = 4 uniformly), which collapses PCS to a constant multiple of RSR and reproduces the RSR ranking exactly: landfilling first, segregation second, processing third, the same ordering as Table III's top three. In the second, Severity ratings for occupational safety (Sev = 4) and context and leadership (Sev = 3) were swapped, reflecting a plausible alternative judgment that governance failures carry graver institutional consequence than individual workplace incidents; this changes their PCS values to 54.6 and 80.0 respectively. The swap is enough to move context and leadership from

last place to fifth, ahead of both collection and transportation and occupational safety, which drops to last. The top four priority domains, landfilling, segregation, processing, and monitoring and reporting, which together account for 75.0% of total PCS and would absorb the first allocation of any facility's independent compliance resource, are stable under both the equal-severity baseline and this targeted re-judgment; it is only the ordering within the bottom three, carrying the remaining 25.0% share, that proves sensitive to how Severity is judged. This suggests that where the Priority Compliance Score ranking matters most, in deciding what to prioritise first, it is driven primarily by the Regulatory-Specific Ratio itself, with Severity judgment mattering more for fine-grained ordering further down the list than for identifying which domains warrant first attention.

*E. Limitations*

1. The 78 sampled requirements represent a structured, representative sample across the seven domains rather than an exhaustive enumeration of every clause and rule provision; a complete requirement inventory would likely shift the precise index values without changing the broad pattern across domains.

2. The Delphi panel (n = 15) is professionally representative but modest in scale, and the Severity ratings used to compute the Priority Compliance Score are expert-consensus judgments rather than measured penalty or incident data from named facilities.

3. The verification-effort model in Section II-F uses a constant illustrative time per requirement and fixed credit coefficients for each classification category; actual verification duration varies with facility size, document management maturity and inspector experience, so the 29.5% reduction is better read as an order-of-magnitude estimate than a guaranteed saving.

4. The framework was developed for municipal solid waste management and has not been tested against the Plastic Waste Management Rules, Bio-Medical Waste Management Rules, or Construction and Demolition Waste Management Rules, each of which operates alongside the SWM Rules, 2016 under India's broader waste-regulation architecture.

*F. Policy and Regulatory Implications*

The findings carry direct implications for the Ministry of Housing and Urban Affairs, the Central Pollution Control Board, and State Pollution Control Boards administering the Solid Waste Management Rules, 2016. First, because Table I shows that a majority of requirements in four of the seven domains are overlapping or complementary with ISO conformity, regulatory inspection protocols for ISO-certified facilities could reference existing ISO audit evidence directly for those domains rather than requiring fully independent demonstration, a practice some certification bodies already follow informally but that has no documented, requirement-level basis in the Indian SWM context until now. Second, the Priority Compliance Score ranking in Table III suggests that regulatory inspection and enforcement resource, which under current practice is applied relatively uniformly across domains, could be weighted toward landfilling and source segregation, the two domains this analysis identifies as carrying the highest independent compliance risk, without necessarily increasing total inspection resource. Third, because 30.8% of all sampled requirements fall into the Regulatory-specific category overall, with landfilling alone contributing six of the twenty-four, this analysis offers empirical support for continuing to treat ISO certification as a complement to, rather than a substitute for, direct regulatory inspection of Indian solid waste facilities, a position current policy already takes informally but that this paper gives an explicit, quantified basis for.

## V. CONCLUSION

This paper set out to answer a fairly specific question that the existing literature leaves open: for a given Indian solid waste management activity, how much of what regulation demands does ISO conformity already deliver, and how much stands entirely on its own? The resulting framework maps 78 sampled requirements from ISO 9001, ISO 14001 and ISO 45001 against the Solid Waste Management Rules, 2016 and associated technical guidance across seven domains, classifying each requirement as overlapping, complementary, partially addressed, or regulatory-specific, and finds integration potential ranging from 30.8% at landfilling and disposal to 63.6% at occupational safety and worker welfare. A Jaccard similarity coefficient borrowed from set theory shows that this integration potential rests on genuine equivalence to very different degrees across domains, occupational safety most directly, landfilling least directly, a distinction the headline integration percentage alone would not reveal. A Priority Compliance Score combining the Regulatory-Specific Ratio with consequence severity identifies landfilling and source segregation together as accounting for nearly half of a facility's independent, ISO-blind compliance risk, and verification-effort modelling suggests a 29.5% reduction in compliance-checking effort when regulatory requirements are verified alongside existing ISO evidence rather than independently. A three-round Delphi panel of fifteen practitioners rated the framework as clear, feasible and useful, with strong statistical agreement (Kendall's W = 0.74), and a separate reliability check found the underlying four-way classification reproducible across independent raters (Cohen's kappa = 0.862). Facilities pursuing both ISO certification and Indian SWM regulatory compliance now have a defensible, quantitative basis for identifying which parts of that compliance burden their management system already carries, and which parts genuinely need independent, dedicated attention, rather than treating the two frameworks as two unrelated paperwork obligations running in parallel.

## AUTHOR CONTRIBUTIONS

Chinmaya Bhat conceived the requirement-level compliance framework; led the identification and classification of ISO and SWM Rules requirements across the seven domains; coordinated the Delphi panel; developed the mathematical formulation of the ISO-Regulatory Integration Index, the Regulatory-Specific Ratio, the Jaccard similarity treatment and the Priority Compliance Score; led the sensitivity and verification-effort analyses; conducted the classification-reliability analysis; prepared the figures and tables; led the mapping of domain-specific technical criteria to the Solid Waste Management Rules, 2016, Schedules I and II, and the associated CPHEEO technical guidance; and drafted, reviewed and approved the final manuscript.

## DATA AVAILABILITY

The illustrative requirement classification counts (Table I), the IRII, RSR and Jaccard values (Tables I and II), the Priority Compliance Score ratings (Table III), and the Python routines used to compute all indices, the verification-effort comparison, the sensitivity analysis, and the classification-reliability statistics reported in this paper are available from the corresponding author upon reasonable request. Raw, individual-level Delphi panellist ratings are withheld to preserve the anonymity guarantee under which the panel was conducted, consistent with standard Delphi methodology [12].

## ETHICS STATEMENT

All Delphi panel participants took part voluntarily, were informed in advance that their individual responses would remain anonymous to both the research team and to other panellists, and provided verbal consent to the use of their aggregated, de-identified ratings in this publication. No personally identifying information beyond the Likert-scale ratings and optional free-text feedback described in Section II-G was collected from panellists at any stage.

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