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Construction Management Capacity and Regulatory Compliance in Documented Building Failures: Three Decades of Kenyan Records, for Nairobi County

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Abstract

Building failure remains a persistent cause of avoidable death and capital loss in rapidly urbanising African cities, yet the empirical literature has tended to treat it either as a technical problem of design or as a governance problem of enforcement, rarely examining the two explanations against a common physical outcome. This study recodes, from first principles, the national register of documented building failures compiled by the National Construction Authority of Kenya for the period 1990 to 2019. The register lists ninety-one rows, one pair of which duplicates a single incident, giving ninety distinct events; thirty-two are located in Nairobi City County. Each event was coded against eight pre-failure deficiency indicators under a rule that admits only conditions the register names, and the complete coded dataset is published as an appendix so that every statistic can be reproduced from the public source. The design is a case-only analysis of buildings that failed. It can describe the composition of the documented failure record and estimate correlates of the extent of failure conditional on a failure having been documented, but it cannot estimate the probability that a standing building will fail, because the register contains no non-failed buildings and no exposure denominators. Structural safety was operationalised as the extent of failure, distinguishing collapse of the primary structural frame (64 events) from localised failure of a secondary element (26 events). Within Nairobi records, poor workmanship is the most frequently named condition, at 59.4 per cent; against the rest of Kenya only inadequate maintenance is significantly more prevalent (21.9 versus 5.2 per cent, $p = 0.031$), while a pre-failure compliance breach is named in 37.5 versus 10.3 per cent of records ($p = 0.005$). Across the national failure corpus, substandard materials is the only indicator associated with escalation from localised defect to frame collapse (OR = 5.07, 95 per cent CI 1.09 to 23.61, p = 0.025); it retains that association under adjustment in a pre-specified reduced model and under Firth penalised estimation across all eight indicators, but it does not survive correction for multiple testing. The models explain between 10 and 16 per cent of the variation in failure extent and classify no better than the majority class, which is itself a finding about how little a short-form incident register records. All multivariable results describe the national failure corpus and not Nairobi City County specifically. Enforcement response is treated throughout as a post-incident governance outcome and is excluded from the compliance index and from every model of failure extent; no such response is recorded in 53.3 per cent of documented failures. The findings support targeted attention to material certification and to the maintenance of the occupied stock, and they identify the absence of a matched non-failed comparison group, and the thinness of recorded attributions, as the two principal barriers to any statement about the occurrence of failure.

Keywords

Structural Safety, Building Collapse, Construction Management Capacity, Regulatory Compliance, Case-Only Design, Firth Penalised Regression, Nairobi City County

1. Introduction

The collapse of occupied buildings is among the few construction failures whose cost is counted in lives rather than in money alone. In Kenya the problem has proved unusually resistant to intervention. Over one hundred collapses have been documented since 1990, more than two hundred people have died, and losses to the economy exceed KES 2.4 billion, a figure that understates the true cost because most of the affected buildings carried no insurance [1]. Successive commissions of inquiry, an audit inspectorate established by executive order and a statutory construction regulator have all been directed at the problem, yet the annual incidence of documented failure rose rather than fell across the period during which those instruments were introduced. A regulatory capacity assessment of the Kenyan built environment concluded that the country's building control system suffers less from an absence of rules than from fragmented institutional responsibility for applying them [2].

Two explanations dominate the literature. The first locates the cause inside the project, in the competence with which the works are managed and executed. Studies of building defects in Malaysia [3] and of failure indicators in Pakistan [4] converge on workmanship, supervision and material quality as the proximate technical determinants of failure, and a recent national assessment of building performance in Kenya identified technical and ethical factors as statistically significant predictors of physical performance [5]. The second explanation locates the cause outside the project, in the design and enforcement of the regulatory regime. Comparative work on regulatory enforcement regimes [6] and on national building regulation compliance in South Africa [7] and Nigeria [8] treats failure as the visible consequence of an enforcement deficit rather than of technical ignorance.

These two accounts are rarely examined against one another. Where management capacity has been studied, the dependent variable has usually been safety behaviour or project performance rather than structural outcome [9], and where compliance has been studied, the outcome has usually been the compliance level itself rather than the physical consequence of non-compliance [10] [11]. The conceptual cost of this separation is considerable. If capacity and compliance are alternative expressions of a single underlying institutional weakness, then a policy that strengthens either will improve safety. If they are distinct, then a policy that strengthens only one will leave the other pathway open. The question is empirical, and it has not been answered for any East African jurisdiction.

A second gap is one of measurement. Almost all the evidence base for sub-Saharan Africa rests on perception surveys administered to construction professionals, in which respondents rate the importance of causes they have not directly observed in the failures under discussion. Perception data of this kind are informative about professional consensus but are weak evidence about causation, because the respondent's rating is itself shaped by the same professional discourse the study seeks to test. Documented failure registers, in which an investigator recorded what was found at a specific site after a specific collapse, are a different and stronger class of evidence. Kenya possesses such a register, assembled by its statutory regulator from investigation files, disaster management incident reports and audit returns [1], and it has not previously been subjected to systematic quantitative analysis.

This paper addresses both gaps. Its objectives are, first, to characterise the construction management capacity deficiencies recorded in documented building failures in Nairobi City County and to examine their association with the extent of failure, and second, to do the same for regulatory compliance deficiencies. Nairobi is selected because it concentrates the phenomenon: as shown below, the county accounts for over a third of all documented building failures in Kenya while holding roughly a tenth of the national population.

What the Register Can and Cannot Support

The design carries a constraint that shapes every claim made in this paper and is therefore stated at the outset rather than deferred to a limitations section. The register records buildings that failed. It contains no non-failed buildings and no denominator describing the exposed stock. It therefore supports two kinds of statement and not a third.

It supports description of the composition of the documented failure record, including comparison of that composition between Nairobi City County and the rest of Kenya. It supports estimation of the association between a recorded pre-failure deficiency and the extent of failure, conditional on a failure having been documented. It does not support any estimate of the probability that a building will fail, nor any statement that one class of deficiency governs whether failure occurs. A difference in the share of failures in which compliance breach was cited is a statement about the composition of the failure register; converting it into a statement about the propensity of non-compliant buildings to fail would require the number of compliant and non-compliant buildings that did not fail, which the register does not contain. Claims of that kind are reserved for future work and are not made here.

The contribution is threefold. The study converts a narrative failure register into a coded analytical dataset and documents the protocol so that the procedure can be replicated in other jurisdictions holding comparable records. It examines the capacity and compliance explanations simultaneously against a physically defined structural outcome rather than against a perceptual proxy. And it separates, within the failure record, deficiencies that are merely prevalent from the single deficiency that discriminates between localised and frame-level failure, a distinction that carries direct implications for where scarce regulatory effort should be placed.

2. Literature Review

2.1. Construction Management Capacity and Structural Outcomes

Construction management capacity refers to the aggregate ability of a project organisation to convert an approved design into a physically sound structure. It is conventionally decomposed into supervision adequacy, the strength of quality assurance and quality control systems, and the technical competence of the contractor and the professional team. Each component has an established evidential basis. Ahzahar *et al.* [3] surveyed contributory factors to building failures and defects and found workmanship-related causes to dominate the observed defect population. Khoso *et al.* [4] developed a set of building failure indicators and reported that construction-stage indicators outranked design-stage indicators in practitioner assessments. Wawak *et al.* [12] concluded from a systematic review that quality outcomes in construction depend more on the operation of quality management systems during execution than on their formal existence in project documentation, a distinction that matters greatly where documentary compliance is easier to achieve than substantive compliance.

The African evidence is consistent in direction but thinner in method. Mahmoud *et al.* [9] proposed a self-regulatory safety framework for building developers, using structural equation modelling on responses from 229 practitioners, and demonstrated that safety administration and safety communication significantly influenced site safety performance. The outcome measured, however, was general safety behaviour rather than structural integrity, so the study cannot speak to collapse risk directly. Mashwama *et al.* [13] examined the cost of poor quality in Eswatini and identified supervision and workmanship as leading contributors, again using perception data. Lagat *et al.* [5] provided the most directly relevant Kenyan evidence, surveying construction sites nationally and finding that technical, ethical and legal factors significantly predicted physical and functional building performance; but performance was defined broadly, the analysis was linear, and construction management capacity was not isolated as a distinct correlate of collapse risk.

A recurring limitation across this body of work is that the several components of management capacity are treated as interchangeable contributors to a single latent construct. Whether workmanship, materials and supervision act through the same causal pathway, or whether some are associated with the frequency of failure while others are associated with its severity, has not been examined. The distinction is not academic: it bears directly on whether a regulator seeking to reduce fatalities should invest in labour accreditation, in material certification, or in supervisory mandates.

2.2. Regulatory Compliance and Structural Outcomes

Regulatory compliance in building control comprises approval and permit validity, the adequacy of staged inspection, and the enforcement response to detected breach. Van der Heijden [6] showed through comparative analysis that enforcement regimes differ less in the content of their rules than in the institutional arrangements through which those rules are checked, and that private-sector involvement in checking produces materially different compliance outcomes. Seiß *et al.* [14] reached a compatible conclusion from expert interviews across several jurisdictions, characterising permit-related inspection as multidisciplinary, fragmented and inconsistently executed, and proposing a conceptual framework for organising inspection responsibilities. Their framework, however, was not validated against measured structural outcomes in any specific city.

In African jurisdictions the compliance literature has concentrated on explaining why compliance fails rather than on what non-compliance produces. Agapiou and Yakubu [8] surveyed 378 Nigerian stakeholders and identified corruption, professional rivalry and capacity constraints as the dominant determinants of non-compliance with structural code standards. Twum-Darko and Mazibuko [7] documented comparable enforcement failures under the South African national building regulations. Omollo [11] identified institutional and resource barriers to effective regulation of the Kenyan building construction industry, and Mwelu *et al.* [15] demonstrated in Ugandan road construction that compliance mediates the relationship between the regulatory framework and project outcomes. Liu *et al.* [16] added a behavioural dimension, showing that commercial pressure shifts contractor compliance attitudes and that organisational ethical climate moderates that shift, a finding foreshadowed by earlier work on the drivers of contractor unethical behaviour [17].

The most directly comparable study is that of Lagat *et al.* [10], who surveyed 261 construction projects in Nairobi City County and found that nine factors explained approximately 67 per cent of the variance in regulatory compliance, with client characteristics, legal framework suitability, task environment, project leader competency, labour quality and regulatory agency proactiveness emerging as significant predictors. That study establishes what determines compliance in the study area. It does not establish what non-compliance produces, because compliance was the dependent variable rather than a correlate of physical outcome. The present study is complementary: it takes the compliance construct that [10] explained and examines it against realised structural failure, within the limits that a case-only register imposes.

2.3. Analytical Gap and Study Contribution

Three shortcomings therefore characterise the existing evidence. Outcomes are typically defined as perceptual or procedural rather than physical, so the chain from deficiency to collapse is inferred rather than observed. The capacity and compliance constructs are studied in separate literatures and have not been entered into a common model, so their relative contribution to the severity of realised failures is unknown. And the reliance on cross-sectional perception surveys means that the evidence base describes what practitioners believe causes failure rather than what was found when failures were investigated. Machine learning applications to collapse data, such as the analysis of Lagos casualty records by Awe *et al.* [18], demonstrate that documented incident registers can support quantitative inference, and reviews of neural network application in construction management [19] confirm the growing methodological appetite for such data. What has been missing is the prior step of converting a national failure register into a coded dataset with a defensible protocol. This study supplies that step and uses the resulting dataset to examine both explanations against a physically defined outcome, while stating explicitly which questions a failure-only corpus can and cannot answer.

3. Materials and Methods

3.1. Research Design and Data Source

The study adopted a retrospective, quantitative document-analysis design applied to a case series of documented failures. The population comprised all building failure events documented in the national register compiled by the National Construction Authority for the period 1990 to 2019 and published as the register table of that Authority's research report on building failure and collapse [1] (pp. 49 to 59), with Nairobi City County as the focal jurisdiction and the remainder of Kenya serving as the comparison group. Five further tabulations in the same source are used in this paper as external checks on the coding rather than as data: the annual incidence chart (p. 48), the stage-at-failure chart (p. 61), the county distribution chart (p. 63), the action-taken chart (p. 63) and the Authority's own five-category classification of attributed causes (p. 65). This register was selected as the evidentiary base for three reasons.

It is the only consolidated national record of building failures assembled by the statutory industry regulator, drawing on the Authority's investigation files, incident reports of the National Disaster Management Unit, audit returns of the National Building Inspectorate and corroborating contemporaneous reports. It records every incident against a consistent attribute set comprising date, county, locality, narrative description, status of the building at failure, attributed cause and action taken, which makes systematic coding feasible. And its thirty-year span is long enough to capture the growth in failure incidence that accompanied the county's rapid vertical densification.

Because the register enumerates only events in which a failure occurred, the design is a case-only one, and two consequences follow that are carried through every analysis reported below. First, no incidence, risk or probability of failure can be computed, since neither a count of buildings at risk nor a comparison group of buildings that did not fail is available. Second, the only outcome that can be modelled is the extent of failure among failures, that is, whether a documented failure involved the primary structural frame or was confined to a secondary element. Prevalence figures reported below describe the share of documented failures in which an indicator was cited. They are not estimates of how often the deficiency occurs in the building stock, and a higher prevalence in one jurisdiction than in another indicates a difference in the composition of recorded failures rather than a difference in risk.

3.2. Extraction Protocol

Records were extracted through a six-step protocol specified in advance. First, the unit of analysis was defined as a single documented failure event, that is, one building or building element whose failure was recorded as a discrete incident with an identifiable date and location. Second, every row of the source register was transcribed verbatim, preserving all original fields. Third, duplicate rows describing the same incident were identified and resolved to a single record. Fourth, records were assigned to counties using the locality field. Fifth, the narrative description, status, attributed cause and action fields were coded against the a priori frame set out in Section 3.4; because incidents frequently carried multiple attributed causes, indicators were coded as non-exclusive binary variables rather than as a single categorical cause. Sixth, the coding was validated against the source's own tabulations of stage, action and attributed cause, and against the four incidents for which the source provides full investigation narratives (pp. 71 to 72 of [1]).

Coding reliability was assessed by having a second coder, working independently from the same frame, code a randomly selected 20 per cent of records. Agreement was quantified using Cohen's kappa, and disagreements were resolved by discussion with reference to the original narrative before the agreed codes were carried forward. The complete coded dataset, one row per documented event, is reproduced as **Table A1** in Appendix A so that every statistic in this paper can be recomputed from the published register without recourse to the authors.

3.3. Reconciliation of Record Counts and Source Inconsistencies

Because the count of records is contested between different tabulations within the source, the reconciliation is set out in full. The register lists ninety-one rows for 1990 to 2019, a total consistent with the eighty-seven documented failures the source plots for 1990 to 2018 in its annual incidence chart together with the four further events it records for 2019.

Two inconsistencies within the source were identified and are disclosed here rather than resolved silently. The first is a duplication: the entry for the 15 October collapse of Karatina Stadium in Nyeri County appears twice, in identical terms, with the same date, description, status, attributed cause and recorded action. The ninety-one rows therefore describe ninety distinct events, and ninety is the analytical corpus used throughout this paper. The second is arithmetical: the national audit total of 14,895 buildings given in the source's executive summary does not agree with its four category counts of 723 very dangerous, 10,791 unsafe, 1217 fair and 2194 safe, which sum to 14,925. The category counts were adopted for the computation of audit proportions in Section 4.1.

The county assignment reconciles as follows. The source's own county distribution chart (p. 63 of [1]) assigns thirty-three events to Nairobi City County. Thirty-two register rows carry an explicit Nairobi locality. The thirty-third is the December 2014 entry recorded under the locality "Kaloleni", which cannot be assigned to Nairobi City County with confidence on the locality field alone and whose status field is recorded as both complete and incomplete, so that stage at failure cannot be coded for it. That record is therefore excluded from the county sub-sample of thirty-two records on which all county-level results are based, and it is carried in the comparison group of fifty-eight records outside the county sub-sample. That placement is conservative: if the record does belong to Nairobi City County, its presence in the comparator attenuates rather than inflates every county-versus-comparator contrast reported below. Extraction completeness for the county is accordingly 97.0 per cent.

3.4. Variable Operationalisation and Coding

Structural safety was operationalised as the extent of the failure that materialised. A case was coded 1 where the primary structural frame failed, that is, where columns, beams, slabs or foundations lost load-bearing integrity and the building collapsed in whole or in progressive part, and 0 where the failure was confined to a secondary element such as a boundary wall, perimeter wall, staircase, parapet, canopy or roof covering while the primary frame remained standing. This physical definition responds to the conceptual criticism raised in Section 2.3, in that it measures a structural consequence rather than a perception of risk. The eight explanatory indicators and their coding rules are set out in **Table 1**.

An indicator was coded 1 only where the narrative description, the status field,

Table 1. Operationalisation and coding of study variables.

Construct	Code	Indicator	Coding rule (1 = named in the register record)
Construction management capacity	x1	Poor workmanship	Poor, substandard or hurried workmanship or construction; incorrect mixing or cement-to-sand ratio; defective formwork or propping
	x2	Substandard materials	Substandard, counterfeit, low-quality or inappropriate materials; inadequate steel reinforcement
	x3	Inadequate design	Poor or inadequate structural design; weak foundation or unverified ground; overload relative to designed capacity; adjacent deep excavation
	x4	Inadequate supervision	Absent or incompetent supervisor or foreman; unregistered contractor; refusal to engage registered contractor or supervising consultants
	x5	Inadequate maintenance	Deterioration or aged fabric; untreated cracking; building already condemned or found unfit for occupation
Regulatory compliance (pre-failure)	x6	Statutory approval breach	Non-compliance with statutory rules or requirements; works without approval or deviation from approved plans
	x7	Site safety requirement breach	Failure to observe statutory site safety obligations; unsafe demolition or excavation method; absent hoarding or safety provision
	x8	Restricted land use	Development on wetland, riparian reserve or water-logged ground
Structural safety (outcome)	y	Extent of failure	1 = collapse of primary frame; 0 = localised element failure
Post-incident governance (reported separately; not a predictor)	z	Enforcement response	Demolition, closure, suspension, prosecution or formal investigation recorded after the failure

All indicators x1 to x8 record conditions present before or at the moment of failure. The field z records action taken after the failure and is excluded from the compliance index and from all models of failure extent.

the attributed cause field or the action field of the register names the condition. Conditions inferred from the circumstances of the event but not recorded by the investigator were not coded. This rule is deliberately conservative. It biases every association reported below towards the null, and it is what makes the dataset in Appendix A reproducible from the published register by an independent coder.

A further field, the enforcement response recorded after the failure, was also coded, but it is treated throughout this paper as a post-incident governance outcome and not as an explanatory variable. An action taken after a building has failed cannot have determined whether that building failed or how far the failure propagated. This field is therefore excluded from the composite indices and from every model of failure extent, and is reported separately in Section 4.6. Earlier drafts of this analysis included it as a ninth predictor; that specification is withdrawn.

The relationship between this frame and the source's own classification requires comment, because the two do not coincide, and the divergence bears on how the results should be read. The Authority classifies each attributed cause into one of five categories; the present frame is more granular, separating supervision and restricted land use from the source's residual categories, and it is more conservative in requiring an explicit citation. Table 2 sets the three available counts side by side: the present coding, the coding used in earlier drafts of this work, and the source's own classification.

Table 2. Indicator counts under the present coding, the earlier coding and the source's own classification.

Indicator	Present coding (n = 90)	Earlier coding (n = 91)	Source classification (n = 91)
Poor workmanship	58	62	51
Substandard materials	21	25	40
Inadequate design	16	28	36
Inadequate supervision	4	21	not separately classified
Inadequate maintenance	10	16	2
Statutory approval breach	8	16	13 (combined with site safety)
Site safety requirement breach	8	15	13 (combined with approval)
Restricted or unsuitable land	3	8	not separately classified

The source classifies each incident into one of five cause categories and does not separate supervision or land use; its non-compliance category combines statutory and safety requirements. Counts are therefore not strictly comparable across columns, and the table is given to show the direction and size of the divergence rather than to align the three schemes.

Three features of Table 2 matter. The present coding and the earlier coding agree closely on poor workmanship and substandard materials, the two indicators that carry most of the analysis below. They diverge most on inadequate supervision, which the register names in only four records although the earlier coding admitted it in twenty-one, and on inadequate design and the three compliance indicators, where the earlier coding again admitted inferred attributions. And on maintenance the present coding sits between the earlier coding and the source, which classifies only two incidents under that heading. Where a result below rests on a sparsely populated indicator, the text says so.

3.5. Composite Indices

Two composite indices were derived from the pre-failure indicators. The Construction Management Capacity Index (CMCI) and the Regulatory Compliance Index (RCI) were scaled from 0 to 100 such that higher scores denote a stronger position on the construct:

$$\text{CMCI} = 100 \times [1 - (x1 + x2 + x3 + x4 + x5)/5] \quad (1)$$

$$\text{RCI} = 100 \times [1 - (x6 + x7 + x8)/3] \quad (2)$$

The Regulatory Compliance Index in this specification differs from the four-item version used in earlier drafts of this work, in which an enforcement response term entered the denominator. That term has been removed for the reason given in Section 3.4. The index is accordingly an index of recorded pre-failure compliance breach only. Because both indices are computed from the recoded indicators, index values reported here are not comparable with those in earlier drafts.

3.6. Analytical Procedure

Analysis was conducted in Python using the SciPy and statsmodels libraries. Prevalence was computed for each indicator and compared between Nairobi City County ($n = 32$) and the rest of Kenya ($n = 58$). The comparison group is the rest of Kenya rather than the full national corpus, because the national corpus contains the county and a county-versus-national contrast therefore compares a group with itself and understates any difference. National figures are reported alongside for context but are not used as the comparator in significance testing. Differences in composite index means were tested by independent-samples t tests.

Bivariate association between each pre-failure indicator and the extent of failure was tested by chi-square tests of independence with the phi coefficient, together with Fisher exact tests and odds ratios with Woolf 95 per cent confidence intervals. Confidence intervals are reported for every odds ratio because several indicator-by-outcome cells contain fewer than ten observations and point estimates alone would convey a false impression of precision. Because nine association tests and nine prevalence contrasts are reported, Holm-adjusted probabilities are given alongside the unadjusted values; the unadjusted probabilities are treated as primary, since each indicator was specified a priori, and the adjusted values are reported so that the multiplicity of the testing is visible to the reader.

Multivariable estimation is constrained by the size of the minority outcome class. The corpus contains twenty-six localised failures against sixty-four frame collapses, so a model containing eight predictors yields 3.3 events per variable, well below the conventional minimum of ten. A reduced model was therefore pre-specified before estimation, containing three predictors chosen on substantive grounds rather than by data-driven selection: substandard materials ($x2$), because material quality is the mechanism through which reserve capacity in the frame is lost; inadequate supervision ($x4$), as the capacity indicator bearing most directly on whether the works were competently overseen; and statutory approval breach ($x6$), as the compliance indicator that bears most directly on whether the works were subject to regulatory scrutiny at all. This specification yields 8.7 events per variable.

Two of those three predictors are sparse under the present coding, with four and eight cited records respectively, so the reduced model is reported both by maximum likelihood and by Firth penalised likelihood, penalisation being the appropriate remedy where sparse cells would otherwise bias maximum likelihood estimates away from the null [20] [21]. A Firth penalised model across all eight pre-failure indicators is reported as a sensitivity analysis. For the penalised models, coefficient tests are penalised likelihood ratio tests and confidence intervals are profile penalised likelihood intervals, both of which behave better than Wald statistics under sparsity. No model of the occurrence of failure was estimated, and none can be estimated from these data. Multicollinearity was assessed by variance inflation factors and a significance threshold of 0.05 was applied throughout.

4. Results

4.1. Distribution of Documented Failures

Nairobi City County accounted for thirty-two of the ninety documented failures, or 35.6 per cent of the national total, more than twice the share of the next most affected county (**Figure 1**). Together with the adjacent Kiambu County, to which 14 events are assigned and which absorbs much of the metropolitan region's residential expansion, the two jurisdictions account for 51.1 per cent of all documented failures in Kenya. Given that Nairobi holds approximately one-tenth of the national population, this represents a concentration of documented failures of roughly three and a half times the population-proportionate expectation. The comparison is between documented events and resident population, not between failures and buildings at risk, and it is therefore a statement about where recorded failures are concentrated rather than about where buildings are most likely to fail.

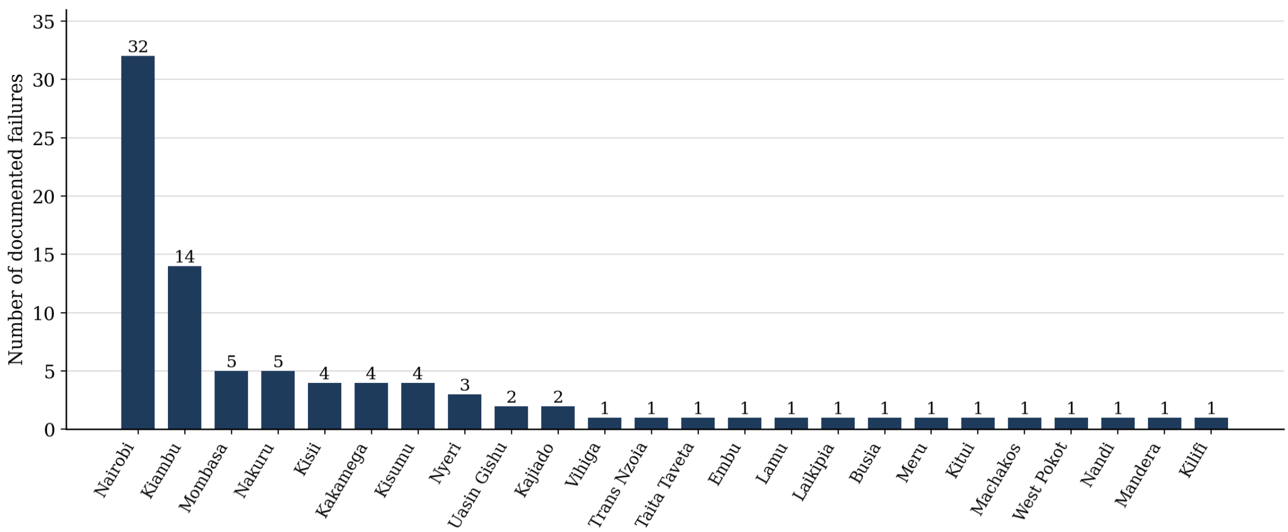

Figure 1. Distribution of documented building failures by county, 1990 to 2019 (n = 89; the December 2014 record of indeterminate locality is omitted).

The temporal profile is strongly skewed towards the most recent decade (**Figure 2**). Two county failures were documented in the 1990s and one in the 2000s, against twenty-nine, or 90.6 per cent of the county total, between 2010 and 2019; within that decade the count rose from twelve in the first half to seventeen in the second. This trajectory should be read with care. Part of the increase reflects genuine growth in exposure as multi-storey residential construction expanded, and part reflects improved surveillance, since the statutory regulator was established in 2011 and the audit inspectorate in 2018. The decline recorded after 2015 is more likely to reflect the closing of the register in 2019 and the lag between an incident and its entry than a real fall in incidence. The defensible inference is that the county carries a large and growing documented burden, not that the earlier decades were free of failure.

Table 3 cross-classifies the county records by construction stage and failure extent. Two features are notable. Failures of completed, generally occupied buildings account for 65.6 per cent of county cases against 53.4 per cent in the rest of Kenya, so Nairobi carries a larger share of failures of the standing stock than the rest of the country, although the difference is not statistically significant in this sample ($p = 0.373$, Fisher exact). And every county failure occurring during construction or demolition involved the primary frame, whereas failures of completed buildings divided almost evenly between frame and element failures; across the national corpus this association is significant, chi-square (2) = 8.408, $p = 0.015$. Overall, 68.8 per cent of county failures involved frame collapse against 72.4 per cent in the rest of Kenya, so the severity profile of county failures mirrors that of failures elsewhere even though the volume does not.

The stage coding can be checked against the source's own tabulation. The Authority reports a national split of 66 per cent complete against 34 per cent

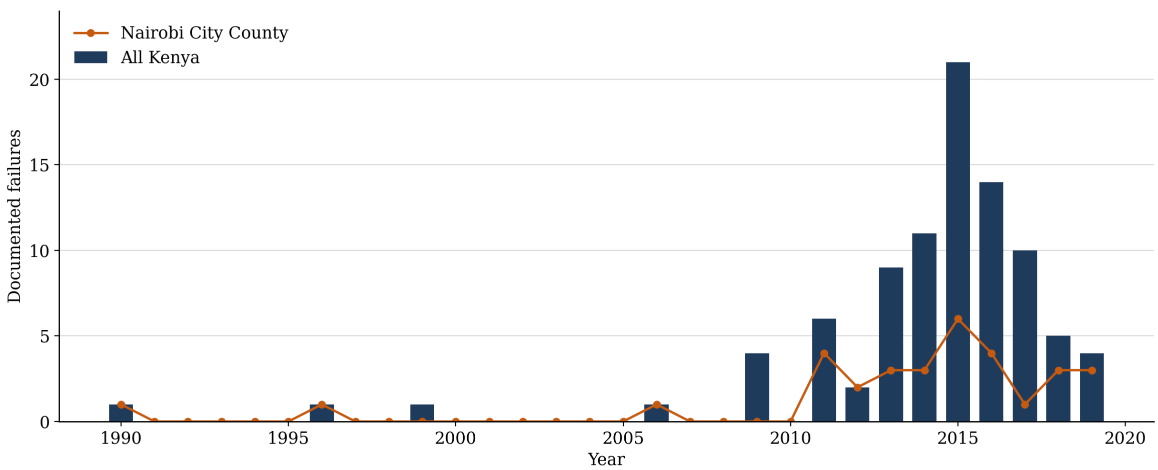

Figure 2. Annual incidence of documented building failures, 1990 to 2019.

Table 3. Construction stage by extent of failure, Nairobi City County (n = 32).

Stage at failure	Localised element failure	Frame collapse	Total	Per cent
Under construction	0	7	7	21.9
Complete and occupied	10	11	21	65.6
Under demolition	0	4	4	12.5
Total	10	22	32	100.0

under construction across the documented cases (p. 61 of [1]). The present coding separates a third category, failure during demolition, from the completed stock; across the national corpus it gives 57.8 per cent complete and occupied, 5.6 per cent under demolition and 36.7 per cent under construction. The two tabulations agree closely once demolition cases are grouped with the completed stock, which supports the stage coding rule and, by extension, the reading of the county profile above.

The audit returns reported in the source register place these events in context. Of 14,925 buildings audited nationally by the National Building Inspectorate, 723 or 4.8 per cent were classified very dangerous, 10,791 or 72.3 per cent unsafe, 1217 or 8.2 per cent fair and only 2194 or 14.7 per cent safe. Documented collapses therefore represent the visible extremity of a far larger population of structurally deficient buildings, and that larger population is the sampling frame from which a matched comparison group would need to be drawn.

4.2. Objective One: Prevalence of Construction Management Capacity Deficiencies

Table 4 and Figure 3 report the prevalence of capacity deficiencies in county records against the rest of Kenya. Poor workmanship is the most frequently named condition in both groups, cited in 59.4 per cent of county failures and 67.2 per cent of failures elsewhere. Twenty-seven of the thirty-two county records, or 84.4 per cent, carry at least one capacity deficiency; the five that do not are records in which the register names only an exogenous trigger such as rainfall or wind, or names no cause at all.

Only one capacity contrast reaches conventional significance. Inadequate maintenance is cited in 21.9 per cent of county records against 5.2 per cent elsewhere, a difference of 16.7 percentage points (p = 0.031, Fisher exact). The remaining four indicators do not differ significantly, and three of them, materials, design and supervision, are in fact somewhat less prevalent in county records than elsewhere. The earlier reading of this county profile, in which supervision deficiency was described as elevated and design deficiency as depressed, is not supported once the coding is restricted to conditions the register actually names. Under Holm adjustment across the nine prevalence contrasts reported in Table 4,

Table 4. Prevalence of construction management capacity deficiencies, Nairobi City County against the rest of Kenya.

Deficiency indicator	Nairobi f (%) n = 32	Rest of Kenya f (%) n = 58	Difference (pp)	Chi-square	p (Fisher)	All Kenya %
Poor workmanship	19 (59.4)	39 (67.2)	−7.9	0.557	0.496	64.4
Inadequate maintenance	7 (21.9)	3 (5.2)	+16.7	5.825	0.031	11.1
Substandard materials	6 (18.8)	15 (25.9)	−7.1	0.583	0.604	23.3
Inadequate design	4 (12.5)	12 (20.7)	−8.2	0.946	0.399	17.8
Inadequate supervision	1 (3.1)	3 (5.2)	−2.0	0.204	1.000	4.4

Indicators are non-exclusive, so percentages sum to more than 100. All chi-square tests carry one degree of freedom.

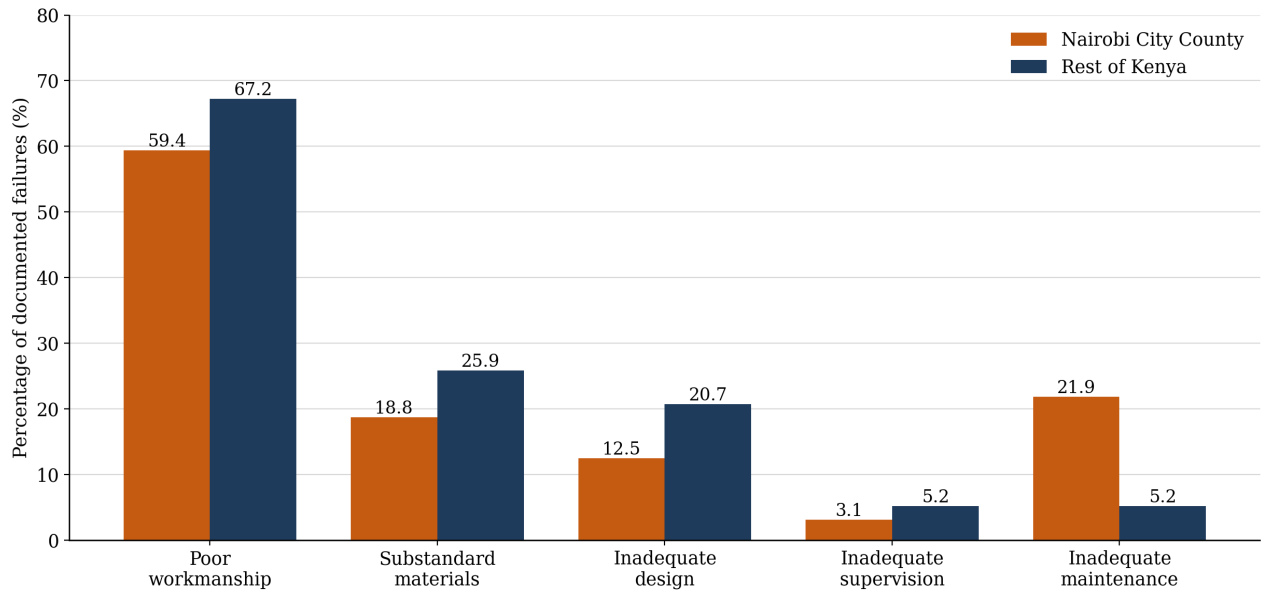

Figure 3. Capacity deficiency prevalence, Nairobi city county against the rest of Kenya.

Table 6 and Table 8, the adjusted probability for maintenance is 0.248, so this too should be read as the strongest signal in the county profile rather than as an established difference.

The CMCI recorded a mean of 76.88 for county failures against 75.17 for failures in the rest of Kenya and 75.78 across the full corpus; the county-versus-rest difference is not statistically significant, $t(88) = 0.530$, $p = 0.598$. Records of county failures are therefore distinguished not by a greater accumulation of capacity deficiencies overall but by a different composition of them.

4.3. Capacity Deficiencies and the Extent of Failure

Table 5 reports the association between each capacity indicator and the extent of failure across the national failure corpus. These results describe the ninety documented Kenyan failures and are not specific to Nairobi City County; the county sub-sample of thirty-two records is too small to support independent estimation.

Table 5. Association between capacity deficiencies and extent of failure, national failure corpus (n = 90).

Indicator	Frame collapse if cited	Frame collapse if not cited	Chi-square	p	p (Fisher)	OR (95% CI)	Holm p
Substandard materials	19/21 (90.5)	45/69 (65.2)	5.000	0.025	0.029	5.07 (1.09 to 23.61)	0.228
Inadequate design	9/16 (56.2)	55/74 (74.3)	2.092	0.148	0.222	0.44 (0.15 to 1.36)	1.000
Inadequate supervision	2/4 (50.0)	62/86 (72.1)	0.908	0.341	0.576	0.39 (0.05 to 2.91)	1.000
Inadequate maintenance	6/10 (60.0)	58/80 (72.5)	0.676	0.411	0.466	0.57 (0.15 to 2.21)	1.000
Poor workmanship	41/58 (70.7)	23/32 (71.9)	0.014	0.905	1.000	0.94 (0.36 to 2.45)	1.000

All chi-square tests carry one degree of freedom. Holm adjustment is applied across the nine association tests reported in Table 5 and Table 7 together with the enforcement test in Section 4.6.

Only substandard materials attains significance: among the twenty-one incidents implicating substandard materials, 90.5 per cent involved frame collapse against 65.2 per cent of the sixty-nine incidents in which materials were not implicated, chi-square (1) = 5.000, p = 0.025, phi = 0.236, OR = 5.07, 95 per cent CI 1.09 to 23.61, confirmed by Fisher exact test (p = 0.029).

Two qualifications attach to the materials result and both are material to its interpretation. The confidence interval runs from 1.09 to 23.61, so while the data are consistent with a substantial escalation in the odds of frame collapse, they are also consistent with an effect close to negligible; the point estimate of 5.07 should not be reported without its interval. And under Holm correction across the nine association tests the adjusted probability is 0.228, so the finding does not survive adjustment for the multiplicity of the testing. The result is best characterised as the strongest signal in the corpus and as a hypothesis meriting replication in an independent register, rather than as an established effect.

Poor workmanship, the most prevalent deficiency, shows no association with severity whatever, with an odds ratio of 0.94 and an interval running from 0.36 to 2.45. The explanation lies in its near-universality: named in 64.4 per cent of all failures including almost every boundary wall and parapet collapse in the register, it is present in both outcome categories and therefore cannot discriminate between them. Within this corpus workmanship is best understood as the pervasive condition under which documented failures occur, while the quality of materials admitted to the site is the condition that distinguishes localised failures from failures that propagate through the frame.

4.4. Objective Two: Prevalence of Pre-Failure Regulatory Compliance Breach

A pre-failure regulatory breach is named in a substantially larger share of county records than of records from elsewhere (**Table 6**, **Figure 4**). At least one breach is cited in 37.5 per cent of Nairobi incidents against 10.3 per cent of incidents in the rest of Kenya, a difference of 27.2 percentage points that is significant at p = 0.005 (Fisher exact). Statutory approval breach is cited in 18.8 per cent of county cases against 3.4 per cent elsewhere (p = 0.022), and site safety breach in 15.6 per cent against 5.2 per cent (p = 0.127). On the two indicators of regulated-party conduct that bear on the building process itself, the county records a markedly weaker profile than the rest of the country, despite hosting the densest concentration of regulatory institutions in Kenya. Under Holm adjustment across the nine prevalence contrasts the adjusted probability for approval breach is 0.198.

It bears repeating that these are shares of documented failures. The statement that breach was cited in 37.5 per cent of county failures against 10.3 per cent elsewhere describes the composition of the failure record. It is not a rate of failure among non-compliant buildings and it cannot be read as evidence that non-compliance makes failure more likely, because the register contains no compliant or non-compliant buildings that did not fail.

Table 6. Prevalence of pre-failure regulatory compliance breach, Nairobi City County against the rest of Kenya.

Indicator	Nairobi f (%) n = 32	Rest of Kenya f (%) n = 58	Difference (pp)	Chi-square	p (Fisher)	All Kenya %
Statutory approval breach	6 (18.8)	2 (3.4)	+15.3	5.962	0.022	8.9
Site safety requirement breach	5 (15.6)	3 (5.2)	+10.5	2.782	0.127	8.9
Restricted or unsuitable land	1 (3.1)	2 (3.4)	-0.3	0.007	1.000	3.3
At least one breach cited	12 (37.5)	6 (10.3)	+27.2	9.504	0.005	20.0

All chi-square tests carry one degree of freedom. The final row is a composite of the three indicators above it and is not counted as a separate test in the Holm adjustment.

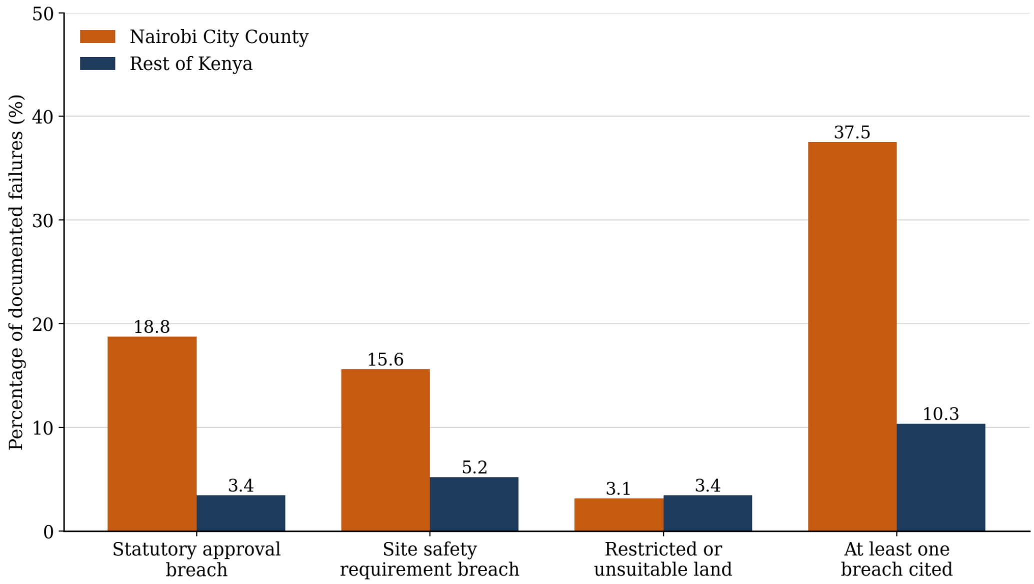

Figure 4. Pre-failure compliance breach prevalence, Nairobi City County against the rest of Kenya.

4.5. Compliance Breach and the Extent of Failure

Table 7 reports the association between the three pre-failure compliance indicators and failure extent across the national corpus. None is associated with the extent of failure. All three point estimates lie below one, all three intervals are wide and include one comfortably, and none approaches conventional significance.

Table 7. Association between pre-failure compliance breach and extent of failure, national failure corpus (n = 90).

Indicator	Frame collapse if cited	Frame collapse if not cited	Chi-square	p	p (Fisher)	OR (95% CI)	Holm p
Statutory approval breach	5/8 (62.5)	59/82 (72.0)	0.317	0.573	0.686	0.65 (0.14 to 2.94)	1.000
Site safety requirement breach	5/8 (62.5)	59/82 (72.0)	0.317	0.573	0.686	0.65 (0.14 to 2.94)	1.000
Restricted or unsuitable land	2/3 (66.7)	62/87 (71.3)	0.030	0.863	1.000	0.81 (0.07 to 9.30)	1.000

All chi-square tests carry one degree of freedom. Enforcement response is not included in this table because it records action taken after the failure; it is reported in Section 4.6.

The reading is that compliance breach, as recorded in this register, is a feature of the circumstances in which failures are documented rather than a condition that determines how far a failure propagates once initiated. In an earlier version of this analysis site safety breach appeared as a significant negative correlate of frame collapse; that result does not survive the recoding and is withdrawn.

4.6. Post-Incident Enforcement Response

The enforcement field produces the most striking descriptive result in the corpus, and its status requires care. In 59.4 per cent of documented county failures no enforcement action was recorded or the record of any action was unclear; in the rest of Kenya the figure was 50.0 per cent and across the full corpus 53.3 per cent (Table 8, Figure 5). In more than one of every two documented building failures in Kenya, including failures causing loss of life, the regulatory record does not disclose that any demolition, closure, suspension, prosecution or formal investigation followed. The county and the rest of the country do not differ materially in this respect ($p = 0.508$, Fisher exact), so the enforcement deficit is a national characteristic rather than a metropolitan one.

Table 8. Post-incident enforcement response recorded in the register.

Enforcement record	Nairobi f (%) n = 32	Rest of Kenya f (%) n = 58	All Kenya f (%) n = 90
Response recorded	13 (40.6)	29 (50.0)	42 (46.7)
No response recorded or unclear	19 (59.4)	29 (50.0)	48 (53.3)

Chi-square (1) = 0.728, $p = 0.508$ (Fisher exact) for the county-versus-rest comparison. This field is a governance outcome recorded after the failure and is not used as a predictor anywhere in this paper.

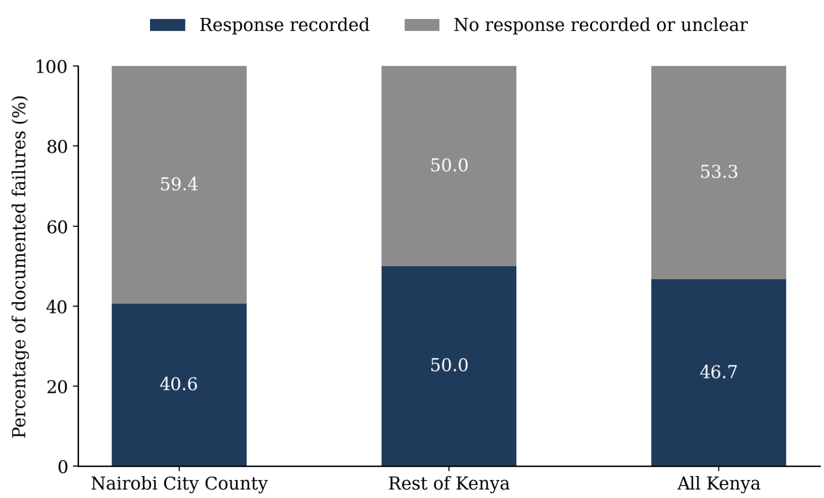

Figure 5. Post-incident enforcement response recorded in the register.

This binary coding can be validated against the source's own eight-category tabulation of action taken (p. 63 of [1]), which records unclear documentation in 40 per cent of cases and no action taken in a further 12 per cent, so that 52 per cent of documented failures generated no traceable regulatory response. The 53.3 per cent obtained here by independent coding is close to that figure. The remaining categories in the source, namely demolitions in 14 per cent of cases, investigations in 11 per cent, closure of sites in 10 per cent, suspension of construction in 6 per cent, repairs recommended in 2 per cent and matters in court in 1 per cent, together account for the responses coded here as recorded. The correspondence is close enough to treat the enforcement finding as a property of the register rather than of the coding rule applied to it.

For completeness, the enforcement field shows no association with the extent of failure across the corpus, chi-square (1) = 0.757, p = 0.384. That result is reported here only to document what the register contains. It carries no causal interpretation in either direction, because the response was recorded after the outcome it would have to precede in order to explain it. Any relationship between the two would more plausibly reflect the influence of failure severity on the probability of an enforcement response than the reverse.

4.7. Analysis of Composite Indices

Table 9 reports the two composite indices. The CMCI does not differ between the county and the rest of the country. The RCI, computed on the three pre-failure compliance indicators, records a county mean of 87.50 against 95.98 in the rest of Kenya, and that difference is significant, t (88) = −2.738, p = 0.007. The index result therefore reproduces at the construct level what Table 6 shows indicator by indicator: county records are distinguished by the compliance conditions named in them rather than by the technical ones.

Table 9. Composite indices computed on the pre-failure indicators.

Index	Nairobi mean (SD)	Rest of Kenya mean (SD)	All Kenya mean (SD)	County versus rest
Construction management capacity index	76.88 (14.47)	75.17 (14.66)	75.78 (14.53)	t (88) = 0.530, p = 0.598
Regulatory compliance index (three items)	87.50 (16.40)	95.98 (12.61)	92.96 (14.56)	t (88) = −2.738, p = 0.007

Both indices are scaled from 0 to 100, with higher scores denoting a stronger position on the construct. The Regulatory Compliance Index reported here excludes the post-failure enforcement term used in earlier drafts and, like the CMCI, is computed on the recoded indicators; neither is comparable with previously reported values.

Neither index correlates with the extent of failure: r = 0.017 (p = 0.871) for the CMCI and r = 0.085 (p = 0.424) for the RCI. That neither aggregate predicts severity while one of their component indicators does is itself informative, and it is the standard consequence of aggregating components that do not act alike into a single score.

The two indices are, however, correlated with one another: r = −0.354, 95 per cent CI −0.523 to −0.159, p = 0.001 across the ninety records. This is a change from the near-zero coefficient reported in earlier drafts, and it must be interpreted with care. A negative correlation between the two indices means that records in which more capacity deficiencies are named tend to be records in which fewer compliance breaches are named, and the reverse. The most economical explanation is not that technically competent projects are less compliant, but that investigators writing a short cause field tend to record either a technical attribution or a regulatory one rather than both. Section 5.6 develops the point. What the coefficient does not establish is that construction management capacity and regulatory compliance are independent constructs, or that they are dependent ones, in the building stock at large: the sample is confined to buildings that failed, and selection on the outcome makes any correlation observed within it a poor guide to the population from which the selection was made.

Variance inflation factors across the eight pre-failure indicators remained below 1.57, well inside the conventional threshold of five, so collinearity does not obstruct joint estimation. That is a statement about the estimability of a model and is a separate matter from the substantive question of whether the two constructs are independent, which these data cannot settle.

4.8. Multivariable Models

The pre-specified reduced model is reported in **Table 10**, by maximum likelihood and by Firth penalised likelihood. Its purpose is to establish whether the materials

Table 10. Pre-specified reduced logistic regression predicting collapse of the primary structural frame, national failure corpus (n = 90).

Predictor	B	S.E.	Wald	p	Exp(B)	95% CI for Exp(B)
Constant	0.693	0.281	6.086	0.014	2.000	1.153 to 3.469
Substandard materials (x2)	1.558	0.795	3.844	0.050	4.750	1.000 to 22.551
Inadequate supervision (x4)	−0.693	1.039	0.445	0.505	0.500	0.065 to 3.830
Statutory approval breach (x6)	−0.182	0.782	0.054	0.816	0.833	0.180 to 3.863

Maximum likelihood. Model chi-square (3) = 6.306, p = 0.098; -2 log likelihood = 101.901; Cox and Snell R squared = 0.068; Nagelkerke R squared = 0.097; classification accuracy = 71.1 per cent. Events per variable = 8.7 on 26 minority-class events.

Predictor	B	S.E.	PLR	p	Exp(B)	95% CI for Exp(B)
Constant	0.680	0.280	6.341	0.012	1.974	1.160 to 3.472
Substandard materials (x2)	1.374	0.743	4.464	0.035	3.951	1.096 to 21.191
Inadequate supervision (x4)	−0.680	1.039	0.520	0.471	0.506	0.073 to 3.511
Statutory approval breach (x6)	−0.228	0.778	0.094	0.759	0.796	0.190 to 3.744

Firth penalised likelihood. PLR is the penalised likelihood ratio statistic on one degree of freedom and the intervals are profile penalised likelihood intervals. Penalised model chi-square (3) = 7.239, p = 0.065; Cox and Snell R squared = 0.067; Nagelkerke R squared = 0.096; classification accuracy = 71.1 per cent.

association survives adjustment for the two other indicators specified a priori, not to identify the best-fitting combination of predictors.

Three results follow. Substandard materials retains a positive and significant coefficient under both estimators: controlling for supervision and approval breach, the odds of frame collapse are 4.75 times greater where substandard materials are named by maximum likelihood (p = 0.050) and 3.95 times greater under penalisation (p = 0.035). Neither supervision nor approval breach approaches significance, and both carry negative coefficients whose intervals span an order of magnitude in each direction, which is what four and eight cited records respectively can support and no more. And the model as a whole is not significant at the 0.05 level, chi-square (3) = 6.306, p = 0.098, with a Nagelkerke R squared of 0.097 and classification accuracy of 71.1 per cent against a no-information rate of 71.1 per cent. The model classifies no better than always predicting frame collapse.

That last point deserves emphasis rather than concealment. An earlier version of this analysis reported a nine-predictor model explaining 31.0 per cent of the variance in failure extent with 80.2 per cent classification accuracy. That model included a post-outcome variable, was estimated at three events per variable, and rested on a coding that admitted inferred attributions. None of those three properties survives scrutiny, and neither does the explanatory power they produced. The honest position is that the eight conditions the register records account for a small fraction of the variation in how far a documented failure propagates, and that most of that variation is driven by structural configuration, occupancy and loading that the register does not capture.

The Firth penalised model across all eight pre-failure indicators is reported in Table 11 as a sensitivity analysis. It confirms the reduced model in every respect that matters.

Table 11. Firth penalised logistic regression across all eight pre-failure indicators, national failure corpus (n = 90).

Predictor	B	S.E.	PLR	p	Exp (B)	95% CI for Exp (B)
Constant	1.630	0.642	8.191	0.004	5.104	1.633 to 5.977
Poor workmanship (x1)	−0.918	0.643	2.376	0.123	0.399	0.156 to 1.273
Substandard materials (x2)	1.421	0.764	4.443	0.035	4.140	1.097 to 22.700
Inadequate design (x3)	−1.013	0.650	2.672	0.102	0.363	0.104 to 1.226
Inadequate supervision (x4)	−0.859	1.145	0.693	0.405	0.424	0.052 to 3.497
Inadequate maintenance (x5)	−0.889	0.798	1.377	0.241	0.411	0.091 to 1.851
Statutory approval breach (x6)	−0.117	0.844	0.022	0.882	0.890	0.197 to 4.643
Site safety requirement breach (x7)	−0.572	0.909	0.449	0.503	0.564	0.106 to 3.234
Restricted or unsuitable land (x8)	−1.093	1.377	0.759	0.384	0.335	0.031 to 4.724

Firth penalised likelihood; PLR is the penalised likelihood ratio statistic on one degree of freedom and the intervals are profile penalised likelihood intervals. Penalised model chi-square (8) = 14.057, p = 0.080; Cox and Snell R squared = 0.113; Nagelkerke R squared = 0.162; classification accuracy = 76.7 per cent. Events per variable = 3.3, below the conventional minimum, which is why this specification is reported as a sensitivity analysis and not as the primary model.

Substandard materials is again the only indicator with a significant coefficient, at an adjusted odds ratio of 4.140 with a profile interval of 1.097 to 22.700 and p = 0.035. The remaining seven coefficients are all negative and none is significant. Their negativity is a property of the reference category rather than a set of protective effects: with materials held constant, the conditions the register names most often are named disproportionately in the localised failures that constitute the reference group. The penalised model is significant at the 0.10 level but not at 0.05, chi-square (8) = 14.057, p = 0.080, and its Nagelkerke R squared of 0.162 again indicates that most of the variation in failure extent lies outside what the register records.

5. Discussion

5.1. What These Data Establish and What They Do Not

An earlier version of this analysis described capacity and compliance as acting through two distinct pathways, with compliance governing whether failure occurs and material quality governing how severe it becomes. The second half of that formulation is supported, subject to the qualifications set out in Section 4.3. The first half is not supported by the design and is withdrawn.

The evidence advanced for it was the observation that a compliance breach is cited far more often in Nairobi records than in records from elsewhere. That observation survives the recoding and is in fact sharper than before: 37.5 per cent against 10.3 per cent. But both figures are shares of documented failures. Neither is a rate of failure among buildings, and their difference is a statement about the composition of the failure register rather than about the propensity of non-compliant buildings to fail. To convert such a comparison into a statement about occurrence would require the number of compliant and non-compliant buildings that did not fail. The register does not contain them and no published Kenyan source currently supplies them. The audit returns summarised in Section 4.1 indicate that such a comparison group could in principle be assembled, since 14,925 buildings were inspected and classified without reference to whether they subsequently failed, and that is the most valuable next step this study can identify.

One comparison in the source makes the point concretely. The Authority reports an estimate that more than 70 per cent of all buildings constructed in Nairobi lack approval from the county government (p. 68 of [1], citing the Architectural Association of Kenya). Statutory approval breach is named in 18.8 per cent of documented county failures. If both figures are even approximately right, then approval breach is recorded in documented failures far less often than it occurs in the standing stock, and the register's citation rate is governed by what investigators chose to write down rather than by exposure. That single observation is enough to show why the prevalence of a compliance breach among failures cannot be read as a measure of the risk it carries, and it points in the opposite direction to the claim that was withdrawn. It is offered as an illustration of the direction of the bias, not as an estimate of its size, since the two figures come from different sources and different populations.

What the data do support is narrower and remains useful. Within the documented failure corpus, one capacity indicator, substandard materials, distinguishes frame collapses from localised failures, and does so under adjustment and under penalisation. No compliance indicator does. Compliance breaches are named substantially more often in county records than in records from elsewhere. These are findings about the anatomy of failures that occurred, and they are informative about where a failure, once initiated, is likely to propagate. They are silent on how often failures begin.

5.2. Materials as the Severity Correlate

That substandard materials is the only indicator distinguishing frame collapse from localised failure is mechanically plausible and practically important. A structural frame that is correctly designed and adequately supervised but built with under-strength concrete or non-conforming reinforcement possesses no reserve capacity; when any element is overloaded, redistribution finds no alternative load path and the failure propagates. Workmanship defects and design shortfalls, by contrast, tend to manifest first in secondary elements where consequences are localised. The association is therefore consistent with a known structural mechanism, which is a reason to take it seriously despite its statistical fragility, though consistency with a mechanism is not itself confirmation of one.

Independent Kenyan evidence points the same way. Figueroa Fernandez [22] examined quality control in Kenyan construction and reported that buildings are approved for occupation on the basis of material strength data produced by testing arrangements that do not reliably detect under-strength work. If certification can be satisfied without the material being sound, then material quality is precisely the deficiency least likely to be caught before occupation and most likely to be discovered only at collapse, which is the pattern the present severity result describes.

The finding gives qualified empirical support in an East African setting to the certification framework Hudson *et al.* [23] developed for Western Australia following the identification of non-conforming products as a systemic risk. It also identifies a specific regulatory gap. The Kenyan statutory regulator holds no explicit mandate over the materials used by contractors: the National Construction Authority Act 2011 does not explicitly control building materials, and the Authority itself identifies this as a gap by contrast with the Construction Industry Development Board of Malaysia, which does hold a mandate over the materials contractors use (pp. 4 to 5 of [1]). The same source records that the Authority holds neither investigative nor prosecutorial powers to enforce its own regulations (pp. 6 to 7 of [1]). Given that material quality is the only severity correlate to emerge from this corpus, the absence of a materials mandate is a plausible candidate for the most consequential omission in the current Kenyan regulatory architecture, and it is one that could be addressed without waiting for the stronger evidence that a matched-comparison study would provide.

5.3. Prevalence Is Not Discrimination

Poor workmanship, though named in 64.4 per cent of documented failures, exhibits no association with severity at all: its odds ratio is 0.94 and its interval is centred on unity. Interventions targeting workmanship alone, such as artisan accreditation schemes, would on this evidence be expected to alter the composition of the failure record without altering the proportion of failures that reach the frame. This is a case in which the most prevalent recorded cause and the only discriminating one are not the same, and where prioritising by prevalence would misallocate regulatory effort. The inference is confined to severity: nothing in these data indicates that workmanship interventions would fail to reduce the number of failures, only that they would not be expected to reduce the share of failures that are catastrophic.

5.4. The Enforcement Record as a Post-Incident Governance Outcome

That no enforcement response is recorded in 59.4 per cent of county failures and 53.3 per cent of failures nationally remains the study's most troubling descriptive result, but its analytical status has been reclassified. It is an outcome of the governance process that follows a failure, not a determinant of that failure or of its extent, and it has accordingly been removed from the compliance index and from every model of failure extent.

Read as a governance outcome, its significance is not merely that sanctions are unimposed but that the regulatory learning cycle is broken. Where investigation produces attribution, attribution can produce reform; the register records no such chain for Kenya, in contrast with the two comparator cases the same source documents (p. 47 of [1]). After the Katowice Trade Hall roof collapse in Poland, the design architects and the building owners were arrested and charged, and Polish building law was amended to require large buildings to undergo technical survey twice each year, with failure to do so itself an offence. After the Hotel New World collapse in Singapore, the owners were jailed for criminal negligence and required to compensate the victims' families, buildings of the same period were re-checked and evacuated where found unsound, and from 1989 every structural design has had to be counter-checked by an accredited checker. In each case investigation produced attribution, attribution produced sanction, and sanction produced a change in the rules. Regulatory frameworks evolve principally in response to documented incident patterns, and comparative work on collapse risk reduction in developing countries identifies the institutionalisation of post-incident investigation as a precondition for that evolution [22]. Where incidents are not conclusively investigated, the learning mechanism is disabled and the regime remains static while the building stock changes around it.

This has a direct methodological consequence for studies of this kind, and the present analysis demonstrates it. The conservative coding rule adopted in Section 3.4 records only what investigators wrote down, and what investigators wrote down is thin: a median of one named condition per record, and none at all in seven records. Supervision, which the practitioner literature identifies as a leading contributor to failure, is named in four records out of ninety. The enforcement deficit therefore degrades the evidence base at the same time as it degrades deterrence, and the small explanatory power of the models in Section 4.8 is in part a measurement of that deficit rather than of the phenomenon.

This result also bears on the compliance literature. Van der Heijden [6] and Seiß *et al.* [14] locate the difficulty of building control in the design of inspection arrangements, and Lagat *et al.* [10] identify regulatory agency proactiveness as a significant determinant of compliance in this very county. The present evidence suggests that a constraint operates one step earlier still. Inspection design and agency proactiveness both presuppose that detected breach carries consequence; where more than half of all documented failures generate no recorded regulatory response, the deterrent premise on which inspection rests is not satisfied. Liu *et al.* [16] showed that commercial pressure shifts contractor compliance attitudes and that ethical climate moderates the shift, and a regime in which failure is unlikely to be followed by sanction supplies precisely the climate in which commercial pressure prevails.

The observation that Nairobi combines the country's densest regulatory presence with much the highest share of failures in which a compliance breach was named is now on firmer ground than before, since the county contrast is significant on approval breach and on any breach cited. The county is served concurrently by the county government, the construction authority, the environmental authority, the building inspectorate and the occupational safety directorate, whose building-control mandates overlap without a clear ordering of responsibility [1]. Institutional density is not institutional effectiveness; where several agencies hold partial mandates, oversight may be diffused rather than intensified, and accountability for the failure to act becomes correspondingly diffuse. An alternative reading must be admitted alongside this one: breaches may simply be more visible, and more likely to be written down, where more inspectors are present. The two readings cannot be separated with these data, and the second is the reason the county contrast is reported as a difference in the composition of the record rather than as a difference in conduct.

5.5. Failures of the Standing Stock

Failures of completed, occupied buildings account for 65.6 per cent of county cases against 53.4 per cent elsewhere, a difference that is not significant, and maintenance deficiency is named four times as often in county records as elsewhere, a difference that is. Taken together these identify a risk category that the regulatory regime is not configured to address, though on evidence that is suggestive rather than conclusive. Building control in Kenya is organised around the approval and construction phases and terminates at occupation. Yet the audit returns indicate that 77.1 per cent of the standing stock is unsafe or very dangerous, and the register shows that most county failures occur after handover. A control regime that concludes at occupation cannot reach the population in which most documented failures occur.

Periodic mandatory structural inspection of existing buildings addresses a demonstrable gap rather than a hypothetical one, and it is not a novel proposal. The National Building Maintenance Policy of 2015 already recommends five-yearly inspection of all categories of buildings, and the Authority's own recommendations add critical inspection of buildings reaching thirty years of age; neither has been given effect through any legal or institutional framework, so no building in Kenya is at present required to be inspected after occupation (pp. 34, 37 and 77 of [1]). The recommendation made here is therefore for the enactment of an existing policy rather than the invention of a new one, and the evidence in this paper indicates which population it should reach first.

5.6. The Attribution Trade-Off

The negative correlation between the two composite indices, r = -0.354 with a confidence interval excluding zero, is the one result in this paper that says more about the register than about buildings, and it is worth stating for that reason. Records in which the investigator named a technical deficiency tend not to be records in which a regulatory breach was named, and the reverse. Nothing in the physics of building failure requires this. Non-compliant projects are, if anything, more likely to be technically deficient, not less. What the coefficient most plausibly measures is a property of short-form incident reporting: an investigator with one line in which to record a cause writes down the attribution that seems primary and omits the others.

Two consequences follow. First, the two constructs cannot be treated as independently measured in this register even though they are conceptually distinct, and any joint model estimated on it inherits the trade-off. Second, and more importantly for policy, the compliance and capacity literatures may be arguing about a distinction that the evidence base itself manufactures. Agapiou and Yakubu [8] and Twum-Darko and Mazibuko [7] both frame non-compliance as arising from the same corruption and capacity constraints that produce poor workmanship. The present data neither confirm nor refute that framing; they show that incident registers of this kind are poorly suited to testing it, and that a register recording all conditions found rather than a single primary cause would be a substantially more valuable instrument.

5.7. Limitations

The first and governing limitation is the case-only design. The dataset comprises only buildings that failed, so the analysis can identify correlates of failure severity conditional on failure and cannot address the unconditional probability that a standing building will fail. Every prevalence figure in this paper is a share of documented failures and none is a risk. A matched sample of non-failed buildings, which the audit returns suggest is feasible to assemble, would be required before any statement about occurrence could be made.

The second is statistical power. Twenty-six localised failures constitute the minority outcome class, which constrains multivariable estimation to a small pre-specified set of predictors, produces wide confidence intervals on every odds ratio reported, and means that county-versus-rest differences of substantive size cannot be resolved. Of the nine association tests and the nine prevalence contrasts reported, none survives Holm adjustment, and every nominally significant result should be treated as a signal requiring replication.

The third is measurement, and it is the limitation most specific to this study. Indicators derive from post hoc causal attributions recorded by investigators in a single short field. They may carry attribution bias, they are demonstrably incomplete, as the approval comparison in Section 5.1 and the attribution trade-off in Section 5.6 both show, and they are sparse: four indicators are named in fewer than ten records each. The conservative coding rule adopted here trades sensitivity for reproducibility, and the trade is deliberate, but it means the results are conditional on what investigators recorded rather than on what was present at the sites. The register is also subject to reporting bias across time, so the temporal trend conflates real growth in incidence with improved surveillance, and the apparent decline after 2015 is more likely an artefact of the register's closing date than a real improvement.

The fourth is the integrity of the source itself. The register contains a duplicated entry and an internal arithmetical inconsistency in the audit totals, both documented in Section 3.3, and the Authority's own county, stage and cause tabulations do not always reconcile with the register rows from which they are derived. The coded dataset in Appendix A allows any reader to check both the coding and the arithmetic against the published register, which is the appropriate response to a source of this kind.

The fifth is scope. All association tests and all multivariable results reported in this paper are estimated on the national failure corpus of ninety records and describe the Kenyan documented failure population generally, not Nairobi City County specifically, although the county contributes 35.6 per cent of that corpus. County-specific results are confined to the prevalence comparisons in **Table 4**, **Table 6** and **Table 8**, the stage cross-classification in **Table 3** and the index comparison in **Table 9**. Readers should not transfer coefficients estimated on the national corpus to the county.

6. Conclusions

This study examined construction management capacity and regulatory compliance in ninety documented Kenyan building failure events from the period 1990 to 2019, thirty-two of them in Nairobi City County. Because the register contains only buildings that failed, the study describes the composition of the documented failure record and identifies correlates of failure extent conditional on failure. It does not, and on this design cannot, establish what makes a building fail.

Regarding the first objective, 84.4 per cent of documented county failures carry at least one construction management capacity deficiency, and poor workmanship is the most frequently named condition in the county and in the country. Against the rest of Kenya, only inadequate maintenance is significantly more prevalent in the county (21.9 against 5.2 per cent, $p = 0.031$); materials, design and supervision are, if anything, named slightly less often in county records. Across the national failure corpus, substandard materials is the only indicator associated with escalation from localised defect to frame collapse (OR = 5.07, 95 per cent CI 1.09 to 23.61), and it retains that association under adjustment for supervision and approval breach and under Firth penalisation across all eight indicators. The estimate is imprecise and does not survive correction for multiple testing.

Regarding the second objective, a pre-failure compliance breach is named in 37.5 per cent of county records against 10.3 per cent of records from the rest of Kenya ($p = 0.005$), and the compliance index differs significantly between the two groups. No compliance indicator is associated with failure severity. These prevalence figures describe the failure record and do not support any claim that compliance governs whether failure occurs. Separately, and as a post-incident governance outcome rather than a determinant, the register discloses no enforcement response in 53.3 per cent of documented failures nationally.

The multivariable models are candid about their own limits. The pre-specified reduced model explains 9.7 per cent of the variance in failure extent and classifies no better than the majority class; the penalised eight-indicator model explains 16.2 per cent. The conditions this register records account for a small fraction of the variation in how far a documented failure propagates. That is a finding about the register as much as about buildings, and it should temper the confidence with which incident registers of this kind are used to support causal claims about construction failure.

Three recommendations follow, stated at the strength the evidence permits. A statutory mandate over construction materials, coupled with testing and certification at the point of delivery to site, addresses the only severity correlate this study identifies and rests on a structural mechanism independent of the statistical result. Periodic mandatory structural inspection of occupied buildings, already recommended in national policy but never enacted, addresses the concentration of county failures in the standing stock and the associated maintenance deficit. And a statutory requirement that every documented building failure be formally investigated, with findings published against a structured schedule of conditions found rather than a single attributed cause, would restore the regulatory learning cycle that the current record shows to be broken, and would remove the principal measurement constraint on analyses of this kind.

Future work should extend the analysis in two directions. The first and more important is the assembly of a matched comparison group of buildings that did not fail, drawn from the national audit population, which would convert the questions this study could not answer into questions that can be. The second is the application of nonlinear predictive methods once a corpus of adequate size and adequate attribute depth is available; the present corpus, with twenty-six minority-class events and a median of one recorded condition per record, does not support flexible model classes any more securely than it supports an eight-predictor logistic regression, and claims made from such models on data of this size and depth should be treated with the same caution urged here.

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Data Availability

The complete coded dataset is reproduced in Appendix A. It is derived entirely from the register table published at pages 49 to 59 of reference [1], which is publicly available, so every statistic in this paper can be independently reproduced.

Author Contributions

Conceptualization, H.K.M. and C.B.O.; methodology, H.K.M.; software, H.K.M.; validation, C.B.O. and D.W.N.; formal analysis, H.K.M.; investigation, H.K.M.; data curation, H.K.M.; writing, original draft preparation, H.K.M.; writing, review and editing, C.B.O. and D.W.N.; visualization, H.K.M.; supervision, C.B.O. and D.W.N. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendix A. Coded Dataset

Every row corresponds to one documented failure event in the register table published at pages 49 to 59 of reference [1], after resolution of the duplicated Karatina Stadium entry described in Section 3.3. Indicators x1 to x8 are coded 1 where the register names the condition and 0 otherwise, following the rules in **Table 1**; z is 1 where an enforcement response is recorded; y is 1 for collapse of the primary structural frame and 0 for localised failure of a secondary element. Region "Rest" denotes the comparison group of fifty-eight records outside the Nairobi City County sub-sample, which includes the December 2014 record of indeterminate locality.

Table A1. Coded dataset derived from the national failure register, 1990 to 2019 (n = 90).

No.	Date	Locality as recorded	Region	Stage	x1	x2	x3	x4	x5	x6	x7	x8	z	y
1	12 Jan 1990	Nairobi, Dagoretti Corner	Nairobi	Construction	1	0	0	0	0	0	0	0	0	1
2	13 May 1996	Nairobi, Moi Avenue	Nairobi	Occupied	0	0	1	0	1	0	0	0	1	0
3	5 Jun 1999	Nyeri	Rest	Construction	1	1	0	0	0	0	0	0	0	1
4	23 Jan 2006	Nairobi, Ronald Ngala Street	Nairobi	Occupied	1	1	0	0	0	0	0	0	0	1
5	30 Jan 2009	Uasin Gishu, Eldoret	Rest	Occupied	1	0	0	0	1	0	0	0	0	0
6	10 Apr 2009	Mombasa	Rest	Construction	1	1	0	0	0	0	0	0	0	1
7	16 Jun 2009	Kisii	Rest	Construction	1	1	0	0	0	0	0	0	0	1
8	19 Oct 2009	Kiambu	Rest	Occupied	1	1	0	0	0	0	0	0	0	1
9	14 Jun 2011	Nairobi, Embakasi	Nairobi	Occupied	0	1	1	0	1	0	0	0	0	1
10	20 Jun 2011	Nairobi, Lang'ata	Nairobi	Occupied	1	0	0	0	0	0	0	0	0	1
11	30 Jul 2011	Nairobi, Ngara	Nairobi	Construction	1	1	0	0	0	0	0	0	0	1
12	17 Sep 2011	Vihiga, Luanda	Rest	Construction	1	0	0	0	0	0	0	0	0	1
13	18 Sep 2011	Kakamega, Mwivona	Rest	Occupied	1	0	0	0	0	0	0	0	0	1
14	19 Sep 2011	Nairobi, Mathare North	Nairobi	Occupied	1	0	0	0	0	0	0	0	0	1
15	7 May 2012	Nairobi, Westlands	Nairobi	Construction	1	0	0	0	0	0	0	0	0	1
16	12 Jun 2012	Nairobi, Mlolongo	Nairobi	Construction	1	0	0	0	0	0	0	0	0	1
17	10 Jan 2013	Trans Nzoia, Kitale	Rest	Occupied	0	0	0	0	0	0	0	0	0	1
18	14 Jan 2013	Nairobi, downtown	Nairobi	Demolition	0	0	0	0	0	0	1	0	0	1
19	16 Jan 2013	Kisumu, Jomo Kenyatta Highway	Rest	Construction	1	1	0	0	0	0	0	0	0	1
20	14 Jul 2013	Kiambu, Ndenderu	Rest	Occupied	1	0	0	0	0	0	0	0	1	1
21	14 Jul 2013	Nairobi, Industrial Area	Nairobi	Occupied	1	0	0	0	0	1	0	0	1	0
22	14 Aug 2013	Taita Taveta, Wundanyi	Rest	Occupied	1	0	1	0	0	0	0	0	0	0
23	2 Sep 2013	Uasin Gishu, Eldoret	Rest	Construction	1	0	0	0	0	0	0	0	0	1
24	3 Sep 2013	Nairobi, Muindi Mbingu Street	Nairobi	Occupied	0	0	1	0	0	0	0	0	0	0
25	28 Nov 2013	Embu, Runyenjes	Rest	Occupied	1	0	0	0	0	0	0	0	0	1
26	14 Jan 2014	Nairobi, Accra Road	Nairobi	Demolition	0	0	0	0	0	0	1	0	0	1
27	1 Aug 2014	Kiambu, Thika	Rest	Demolition	1	0	0	0	0	0	0	0	1	1

Continued

28	14 Sep 2014	Lamu, Pate Island	Rest	Construction	1	1	0	0	0	0	0	0	1	1
29	2014	Laikipia, Nanyuki	Rest	Construction	1	1	0	0	0	0	0	0	1	1
30	Nov 2014	Kiambu, Ruaka	Rest	Occupied	1	1	0	0	0	0	0	0	1	1
31	Nov 2014	Mombasa	Rest	Construction	1	0	1	0	0	0	0	0	1	1
32	Nov 2014	Nyeri, Skuta	Rest	Construction	1	0	1	0	0	0	0	0	1	1
33	Nov 2014	Nairobi, Baba Dogo	Nairobi	Occupied	1	0	0	0	1	1	0	0	0	0
34	Dec 2014	Nairobi, Kasarani	Nairobi	Occupied	1	0	0	0	1	1	0	0	1	0
35	17 Dec 2014	Kiambu, Thika Makongeni	Rest	Occupied	1	0	1	0	0	0	0	0	1	1
36	Dec 2014	Kaloleni	Rest	Occupied	0	0	1	0	0	0	0	0	0	1
37	4 Jan 2015	Nairobi, Huruma	Nairobi	Occupied	1	1	0	0	0	0	0	0	1	1
38	2 Apr 2015	Nairobi, Roysambu	Nairobi	Construction	1	0	0	0	0	1	0	0	1	1
39	4 Feb 2015	Kakamega, Milimani	Rest	Construction	0	0	0	0	0	0	1	0	0	1
40	15 Apr 2015	Kiambu, Thika	Rest	Occupied	1	1	0	0	0	0	0	0	0	1
41	15 Apr 2015	Nairobi, Muthurwa	Nairobi	Demolition	0	0	0	0	0	0	1	0	0	1
42	16 Apr 2015	Kisii, Jogoo Estate	Rest	Occupied	1	0	0	0	0	0	0	0	0	1
43	26 Apr 2015	Kiambu, Kiambaa	Rest	Construction	1	0	0	0	0	0	0	0	1	1
44	29 Apr 2015	Kiambu, Kikuyu	Rest	Construction	1	1	0	0	0	0	0	0	1	1
45	Apr 2015	Nakuru, Kiti Estate	Rest	Occupied	1	0	1	0	0	0	0	0	0	0
46	13 May 2015	Nairobi, South B	Nairobi	Occupied	1	1	0	0	0	0	0	0	1	0
47	25 May 2015	Mombasa, Nyali	Rest	Occupied	1	0	0	0	0	0	0	0	1	1
48	3 Jun 2015	Kisumu	Rest	Construction	1	0	0	0	0	1	0	0	1	1
49	2 Jul 2015	Kisumu, Manyatta	Rest	Occupied	0	1	0	0	0	0	0	0	1	1
50	7 Jun 2015	Nairobi, Lower Kabete	Nairobi	Construction	1	0	0	0	0	1	0	0	1	1
51	14 Jul 2015	Nairobi, Zimmerman	Nairobi	Occupied	1	0	0	0	0	0	0	0	0	1
52	6 Sep 2015	Kajiado, Ongata Rongai	Rest	Construction	1	1	0	0	0	0	0	0	0	1
53	26 Sep 2015	Kiambu, Lower Kabete	Rest	Construction	1	0	0	0	0	0	0	0	0	1
54	9 Oct 2015	Busia	Rest	Occupied	1	0	0	0	0	0	0	0	0	1
55	28 Oct 2015	Kiambu	Rest	Occupied	1	0	0	0	0	0	0	0	0	0
56	12 Nov 2015	Meru, Chuka	Rest	Occupied	0	0	0	0	0	0	0	0	0	0
57	19 Nov 2015	Kitui	Rest	Construction	1	0	0	0	0	0	0	0	0	0
58	7 Jan 2016	Nakuru	Rest	Occupied	0	0	1	0	0	0	0	0	0	0
59	28 Apr 2016	Nairobi, Lenana Road	Nairobi	Occupied	1	0	0	0	0	0	0	0	1	0
60	29 Apr 2016	Nairobi, Huruma Ngei	Nairobi	Occupied	0	0	0	0	0	1	0	0	0	1
61	9 May 2016	Mombasa, Nyali	Rest	Occupied	1	0	0	0	0	0	0	0	1	0
62	1 Jul 2016	Nakuru	Rest	Occupied	0	0	0	1	0	0	0	0	1	1

Continued

63	2 Aug 2016	Nairobi, Westlands	Nairobi	Occupied	0	0	0	0	0	0	0	1	0	0
64	21 Aug 2016	Kajiado, Ngong	Rest	Construction	1	0	0	0	0	0	1	0	1	0
65	24 Sep 2016	Nairobi, Huruma	Nairobi	Occupied	1	0	0	0	0	0	1	0	1	0
66	30 Sep 2016	Machakos, Athi River	Rest	Occupied	0	0	1	1	0	0	1	0	1	0
67	30 Sep 2016	Kiambu, Ruaka	Rest	Construction	0	0	0	0	0	0	0	0	1	0
68	10 Nov 2016	Kisii, Daraja Moja	Rest	Construction	0	0	1	0	0	0	0	0	1	1
69	5 Nov 2016	Kakamega, Bukhungu	Rest	Construction	1	0	0	0	0	0	0	0	1	0
70	23 Nov 2016	Kiambu, Ruiru	Rest	Occupied	0	0	0	0	0	1	0	1	0	1
71	23 Nov 2016	Kiambu, Juja	Rest	Construction	0	0	1	0	0	0	0	0	0	1
72	19 Feb 2017	Nakuru, Gilgil	Rest	Construction	1	1	1	0	0	0	0	0	1	1
73	28 Feb 2017	West Pokot, Chepareria	Rest	Occupied	1	0	0	0	0	0	0	0	1	1
74	9 May 2017	Mombasa, Kizingo	Rest	Occupied	0	0	1	0	0	0	0	0	0	0
75	12 Jun 2017	Nairobi, Embakasi	Nairobi	Occupied	0	0	0	0	1	0	0	0	0	1
76	21 Sep 2017	Nandi, Kapsabet	Rest	Occupied	0	0	0	0	1	0	0	0	0	1
77	11 Oct 2017	Kisii, Mwembe	Rest	Construction	0	0	0	0	0	0	0	1	1	1
78	12 Oct 2017	Mandera	Rest	Construction	1	1	0	0	0	0	0	0	1	0
79	15 Oct 2017	Nyeri, Karatina	Rest	Occupied	0	0	0	0	0	0	0	0	1	0
81	22 Oct 2017	Nakuru	Rest	Occupied	0	0	0	0	1	0	0	0	1	1
82	22 Oct 2017	Kakamega	Rest	Occupied	1	0	0	1	0	0	0	0	1	0
83	3 Jan 2018	Nairobi, Pipeline	Nairobi	Demolition	0	0	0	1	0	0	1	0	1	1
84	15 Mar 2018	Kiambu, Juja	Rest	Construction	0	0	0	0	0	0	0	0	1	1
85	17 Mar 2018	Nairobi, Ruai	Nairobi	Occupied	0	0	0	0	1	0	0	0	1	1
86	3 Jun 2018	Nairobi, Huruma Ngei	Nairobi	Occupied	0	0	0	0	1	0	0	0	1	1
87	26 Oct 2018	Kilifi, Malindi	Rest	Occupied	0	0	0	0	0	0	0	0	0	1
88	11 Mar 2019	Kisumu, Manyatta	Rest	Occupied	1	1	0	0	0	0	0	0	1	1
89	8 Sep 2019	Nairobi, Kabiria Riruta	Nairobi	Construction	0	0	1	0	0	0	0	0	0	1
90	12 Sep 2019	Nairobi, Industrial Area	Nairobi	Occupied	1	0	0	0	0	0	0	0	0	0
91	23 Sep 2019	Nairobi, Dagoretti	Nairobi	Occupied	1	1	0	0	0	0	0	0	1	1

Stage abbreviations: Construction = under construction; Occupied = complete and occupied; Demolition = under demolition. The stage of the December 2014 record of indeterminate locality is recorded as Occupied for the national tabulation only; that record is excluded from Table 3.