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School building conditions and chronic absenteeism within socioeconomic contexts: a component-level statistical analysis in New York State

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Abstract

Purpose – Chronic absenteeism has surged since the COVID-19 pandemic, yet the role of school building conditions as correlates of attendance remains under-specified at the system level. This study links chronic absenteeism rates for New York public school buildings with standardized, component-level data from the 2024 New York State Building Condition Survey.

Design/methodology/approach – Using a Bonferroni-adjusted multi-method statistical framework aligned with variable types (group means comparisons, correlations, and multiple linear regression with Socioeconomic Status (SES) control), we identify specific systems, materials, and practices associated with student absence.

Findings – Socioeconomic context accounted for a substantial proportion of the variance in chronic absenteeism ($R^2 = 0.40$), and over half of the building features significant in bivariate analysis lost significance after controlling for nine neighborhood-level SES variables. Among building features, indoor air quality factors showed the strongest independent associations: indoor pesticide use was associated with an approximately 8.1 percentage-point increase in absenteeism ($b = 8.09$, $p < 0.001$), mold-susceptible ceiling materials with a 6.6 percentage-point increase ($b = 6.57$, $p < 0.001$), and buildings tested for radon below 4 pCi/L with a 4.1 percentage-point decrease ($b = -4.14$, $p = 0.04$). Recent renovations were also associated with a 5.5 percentage-point reduction in absenteeism ($b = -5.54$, $p < 0.001$). In contrast, aggregate facility ratings and perceived conditions (e.g. cleanliness, lighting) showed no independent association.

Research limitations/implications – The study is cross-sectional and observational, identifying associations rather than causal effects, and relies on inspector-assessed building conditions. Reduced sample sizes in some categories and small subgroups for certain features limit statistical power and reliability. Residual confounders not captured by the nine SES controls (e.g. district policies, transportation access) may remain. The restriction to New York State public school buildings limits cross-jurisdictional generalizability.

Practical implications – Facility managers and district leaders can use the findings to prioritize component-level actions that are more directly linked to attendance-relevant exposures, including reviewing indoor pesticide practices, scheduling replacement of mold-susceptible ceiling materials during renovation cycles, maintaining systematic radon testing, and using SES-adjusted evidence when ranking capital projects.

Originality/value – This study provides one of the first component-level, system-specific assessments linking school building conditions to chronic absenteeism across a large sample of New York State public school buildings using standardized engineer/architect survey data. It moves beyond composite "facility quality" scores to identify specific building features, including maintenance status, indoor pesticide use, moisture/mold-prone materials, radon practices, and water piping types that are independently associated with absenteeism and align with plausible health pathways. The findings offer a prioritization view for infrastructure management and operation, targeting building components strongly associated with attendance disparities.

Keywords Chronic absenteeism, School building condition, Indoor air quality, Socioeconomic status

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1. Introduction

Chronic absenteeism has intensified nationally, especially after COVID-19 (Chang, 2025), and is now recognized as a critical early warning indicator of long-term academic risk. Defined as missing 10% or more of enrolled school days for any reason, it predicts diminished academic achievement (Gottfried, 2010), lower reading proficiency, reduced graduation rates (Allensworth and Easton, 2007), and elevated dropout risk (Kearney, 2008). In New York, rates have remained persistently high post-pandemic (DiNapoli, 2024). While research cites health, socioeconomic barriers, and student disengagement as major contributors (Balfanz and Byrnes, 2012), the school's physical environment, an active system that shapes student health, comfort, and safety (Haverinen-Shaughnessy *et al.*, 2015), remains an overlooked yet highly important factor. Evidence consistently shows that poor or aging facilities are linked to higher absenteeism rates (Durán-Narucki, 2008) through pathways such as inadequate indoor air quality (Simons *et al.*, 2010), thermal discomfort, deteriorated aesthetics (Maxwell, 2016), and safety concerns.

Despite this established relationship, current knowledge rarely identifies which specific building systems most strongly influence attendance. Much of the literature relies on broad facility-quality indices or composite ratings (Tanner, 2009), which limits their usefulness for targeted capital planning. Component-level analysis is necessary because aggregate scores obscure how distinct parts of school buildings (e.g. utility systems and building envelopes) affect students and necessitate targeted interventions. Further, many prior studies depend on subjective assessments from school staff rather than standardized, expert evaluations (Cash, 1993). As a result, policymakers and district leaders lack the granular, actionable evidence needed to prioritize investments that directly reduce absenteeism. Moreover, most prior studies do not control for socioeconomic confounders, thereby risking omitted-variable bias (Durán-Narucki, 2008; Simons *et al.*, 2010). A systematic review of 55 studies found that socioeconomic status is consistently associated with school attendance, yet studies examining facility effects rarely account for these confounders simultaneously (Sosu *et al.*, 2021).

At the same time, absenteeism is shaped by a set of dominant non-building factors, including poverty, family instability, transportation barriers, and school climate (Balfanz and Byrnes, 2012). Socioeconomic characteristics, such as household income, housing tenure, racial/ethnic composition, and parental educational attainment, are consistently identified as strong correlates of attendance (Lim *et al.*, 2019; Klein *et al.*, 2020; Sosu *et al.*, 2021). As a result, observed associations between building conditions and absenteeism may reflect underlying socioeconomic disparities rather than independent facility effects. Without explicitly accounting for these confounders, it is not possible to distinguish whether building characteristics contribute meaningfully to absenteeism or simply proxy for broader community conditions.

This study addresses these gaps by linking standardized, component-level data from the 2024 New York State Building Condition Survey (BCS): a legally mandated assessment conducted by licensed architects and engineers using consistent protocols (Office of Facilities Planning, 2020), with chronic absenteeism rates for public school buildings during the 2023–2024 academic year. Unlike composite indices, the BCS provides granular, system-specific information by decomposing facilities into discrete, evaluated components. The analysis examines building features across five categories using statistical methods tailored to variable types and controls for nine neighborhood-level socioeconomic variables. This framework enables the identification of facility characteristics that are independently associated with absenteeism while accounting for socioeconomic context.

This study addresses two research questions: (1) Which specific school building systems and components are independently associated with chronic absenteeism after controlling for socioeconomic characteristics? (2) Do aggregate facility ratings show comparable associations with absenteeism relative to component-level measures?

2. Literature review

This study is grounded in several distinct but intersecting domains of research: the drivers and consequences of chronic absenteeism, the general relationship of facility quality on educational outcomes, and the specific mechanistic pathways through which individual building systems influence student health, comfort, and attendance.

2.1 School facility conditions and student attendance: mechanisms and measurement gaps

A substantial body of research links the physical condition of school facilities to student outcomes, with better-maintained buildings consistently associated with higher attendance, stronger academic performance, and improved behavior (Earthman, 2002). These associations have been replicated across regions and student populations, establishing facility quality as a substantive factor of educational opportunity rather than a purely operational concern (Buckley *et al.*, 2005). Research focusing on New York schools provides additional insight into how these effects materialize. Poor building conditions are most strongly linked to absenteeism in schools serving lower-income communities and younger grades, indicating that infrastructure inequities compound existing socioeconomic vulnerabilities (Simons *et al.*, 2010). Maintenance emerges as a critical pathway: schools with large deferred maintenance backlogs experience higher absenteeism, lower academic achievement, and elevated teacher turnover, whereas schools that invest in systematic and preventive maintenance show higher average daily attendance and an improved school climate (Dickerson and Ackerman, 2016).

Beyond these operational pathways, facility quality also serves as a symbolic and psychological signal. Well-maintained buildings convey care, safety, and respect to students, families, and staff, shaping motivation, engagement, and the willingness to attend school (Uline and Tschannen-Moran, 2008). In contrast, deteriorated conditions can trigger emergency closures and repair-related disruptions, reducing instructional time for entire school communities (GAO, 2020). However, these two pathways do not always align: a building may receive favorable visual condition ratings while harboring health-relevant exposures, such as mold-susceptible materials or inadequate ventilation, that are not apparent during walkthrough inspection (Haverinen-Shaughnessy *et al.*, 2015; Toyinbo *et al.*, 2019). This potential divergence between what assessments capture and what affects student health is a central concern of the present study.

Prior research has also been limited in two respects. First, most studies evaluate facility condition using aggregate indices or composite ratings (Cash, 1993; Durán-Narucki, 2008; Tanner, 2009), which cannot distinguish which specific system requires attention. Second, even disaggregated condition scores may measure the wrong dimension: visual ratings reflect surface-level appearance rather than health-relevant characteristics such as material composition, chemical treatment practices, or ventilation adequacy (Mendell *et al.*, 2013; Toyinbo, 2023). The present study addresses both limitations by including material, practice, and system-type variables alongside condition scores across five building categories, enabling a direct comparison of which measurement dimension is more strongly associated with attendance.

2.2 Core building systems and infrastructure impacts on student health and attendance

The building's core infrastructure, including its envelope and utility systems, forms the foundation for occupant health, safety, and comfort (Awada *et al.*, 2021). Failures in these systems are well-documented as associated with student well-being and attendance. Deficiencies in the building envelope are a major source of moisture intrusion, condensation, and mold (Mendell *et al.*, 2011). These conditions are associated with respiratory illness, asthma exacerbations, allergic reactions, and higher absenteeism (Sheehan *et al.*, 2010). Visible water damage, roof leaks, dampness, and window condensation are associated with health complaints and illness-related absences in schools (Kreiss, 2013). The envelope also influences thermal comfort and energy efficiency; poorly insulated or leaky buildings experience uncomfortable temperature swings that are associated with reduced classroom comfort and lower attendance (Wargocki and Wyon, 2007).

Water service infrastructure is just as important to student health. Pipe material and condition influence water quality through corrosion, lead leaching, and microbial growth, with documented links ranging from gastrointestinal illnesses in schools with aging plumbing systems (Jasper *et al.*, 2012) to serious lead exposure in cases of systemic infrastructure failure (Sauve-Syed, 2024). Copper piping provides antimicrobial properties and greater corrosion resistance than galvanized or lead alternatives (Mendell *et al.*, 2011), offering a plausible link between pipe material and student health outcomes. These findings support including water service piping material and condition as variables in the current analysis.

2.3 Indoor environmental quality and air quality as determinants of student absenteeism

Indoor Environmental Quality (IEQ), including lighting, acoustics, aesthetics, and indoor air quality (IAQ), influences student absenteeism through health symptoms and discomfort, with absenteeism often mediating the link between poor IEQ and reduced academic performance (Haverinen-Shaughnessy *et al.*, 2015; Sadeghi *et al.*, 2021). Specific IEQ pathways are well documented across acoustic, thermal, and lighting dimensions: daylit classrooms improve mood and reduce absences (Heschong *et al.*, 2002); poor classroom acoustics elevate stress and absenteeism (Shield and Dockrell, 2008); and thermal discomfort contributes to illness-related absences (Wargocki and Wyon, 2007). General school appearance and cleanliness further shape motivation to attend (Uline and Tschannen-Moran, 2008).

Poor IAQ, marked by pollutants, allergens, and elevated CO_2, is strongly associated with respiratory symptoms, asthma attacks, and increased absenteeism (Mendell and Heath, 2005). Classroom CO_2 levels above 1,000 ppm are specifically linked to higher illness-related absences (Gaihre *et al.*, 2014). Asthma, a leading cause of school absences, is exacerbated by building triggers such as mold and particulates (Phipatanakul, 2006; Meng *et al.*, 2012). Indoor and ambient particulate exposures—including low-level PM2.5 and ozone, total suspended particulates, and airborne bacteria—are associated with elevated K-12 absenteeism, with disproportionate effects in disadvantaged schools (Abou Taleb *et al.*, 2002; Mendoza *et al.*, 2020).

Ventilation and filtration improvements demonstrably reduce both pollutants and absences: enhanced ventilation has been associated with up to a 3.4-percentage-point reduction in absenteeism (Mendell *et al.*, 2013; Allen *et al.*, 2016), and quasi-experimental evidence supports a causal interpretation of infrastructure-level upgrades (Heissel *et al.*, 2022).

Despite well-established links between individual IEQ parameters and student health, most studies examine these parameters in isolation rather than simultaneously assessing multiple building features across a large school sample, and few control for socioeconomic confounders when evaluating facility effects on attendance. This gap is compounded by the growing complexity of indoor environmental control: as buildings incorporate sensor-driven ventilation and automated systems, interactions between window operation, occupant behavior, and mechanical controls jointly shape actual exposure conditions in ways that single-parameter assessments cannot capture (Karamoozian *et al.*, 2026). Furthermore, evidence from green-certified buildings shows that design-stage environmental targets frequently diverge from operational performance due to maintenance, commissioning, and occupancy challenges (Karamoozian and Zhang, 2025), reinforcing the idea that realized indoor conditions, not design ratings, determine occupant attendance outcomes.

These findings underscore the need for empirical, multi-feature analyses that assess how specific building characteristics relate to student attendance, while accounting for socioeconomic context, as the approach adopted in the present study.

2.4 Socioeconomic determinants of school attendance

Socioeconomic status (SES) is among the most widely documented correlates of school absenteeism: a systematic review of 55 studies found that financial-resource measures such as free and reduced-price lunch (FRPL) eligibility provide the strongest single-dimension evidence of an SES–absenteeism link (Sosu *et al.*, 2021). The pathways through which SES influences attendance are multidimensional. Low-income families face higher rates of childhood illness, food insecurity, housing instability, and limited access to transportation, all of which increase the likelihood of missed school days (Ready, 2010; Lim *et al.*, 2019). Housing tenure is a particularly strong predictor; students in socially rented or unstable housing experience higher absenteeism across all forms of absence—including sickness, truancy, and temporary exclusion to peers in owner-occupied housing (Klein *et al.*, 2020). Racial and ethnic disparities in attendance are well documented and persist even after adjusting for income, with Black and Hispanic students experiencing disproportionately higher chronic absenteeism (Balfanz and Byrnes, 2012; Lim *et al.*, 2019). Among sociocultural dimensions, parental education is uniquely associated with attendance: lower parental education predicts higher sickness-related and overall absences, potentially reflecting differences in health literacy and engagement with educational institutions (Klein *et al.*, 2020; Klein and Sosu, 2024). Neighborhood-level deprivation compounds these individual-level factors through environmental stressors such as exposure to crime, poor infrastructure, and limited access to services (Balfanz and Byrnes, 2012). These findings underscore that socioeconomic context operates through interacting dimensions rather than a single pathway, and any study examining facility effects on attendance must account for this confounding structure.

3. Methodology

3.1 Data sources and sample

Chronic absenteeism data were obtained from the New York State Education Department's public reporting system, which annually releases school-level accountability indicators (NYSED, 2025). The dependent variable is defined as the percentage of students enrolled for at least 10 instructional days who miss 10% or more of those days. In the 2023–2024 academic year, chronic absenteeism across the sampled schools averaged 22.90%, with a standard deviation of 16.61%.

The unit of analysis is the individual school building. Building characteristics were obtained from the 2023–2024 BCS, mandated by the New York State Education Department and covering all public-school buildings across the state. In our analysis, school buildings were excluded if they lacked data on chronic absenteeism, had incomplete BCS records, or did not serve an instructional purpose (e.g. library, parking). Building components were further excluded if they exhibited substantial missingness or were not relevant to classroom settings. The original sample included 922 school buildings; after merging BCS records with chronic absenteeism data and applying exclusion criteria, the final analytic sample comprises 462 public school buildings.

To account for socioeconomic confounding, census block group–level SES variables were included as controls. These variables were derived by inverse geocoding each school building's address to obtain geographic coordinates, which were then spatially matched to the corresponding census block group using the U.S. Census Bureau's 2024 American Community Survey (ACS) 5-year estimates. Nine socioeconomic variables were included as controls (Table 1).

3.2 Building characteristics

The independent variables were derived from 57 distinct features in the 2024 BCS, selected based on documented or plausible mechanistic links to student health and attendance. Variables unrelated to classroom environments were excluded (e.g. "exterior accessible route to building"). Features with more than 20% missing values were excluded (e.g. water service piping type: lead and are crevices and holes in walls); missingness in these features was

Table 1. Summary of building characteristics categories and feature type

Category	Subcategory	Features
Socioeconomic Status (SES) ($n = 9$)	Income	Mean household income ($)
	Education	Bachelor's degree or higher (%)
	Housing	Renter-occupied households (%)
	Demographics	Female (%), Single parent (%), Asian (%), Black (%), White (%), Hispanic (%)
Foundational Building Characteristics ($n = 6$)	General attributes	Building age (years), Gross floor area (sq. ft.), Number of floors, Number of instructional classrooms
	Maintenance history	Renovations in the past 12 months (Binary)
	Overall assessment	Overall building rating (4-points scale)
Building Envelope ($n = 9$)	Chimneys	Presence of chimneys (Binary), Chimneys ERUL (years), Chimneys condition rating (5-points scale)
	Windows	Presence of windows (Binary), Windows ERUL (years), Windows condition rating (5-points scale)
	Skylights	Presence of skylights (Binary), Skylights ERUL (years), Skylights condition rating (5-points scale)
Utility Systems and Infrastructure ($n = 12$)	Site gas	Site gas ERUL (years), Site gas condition rating (5-points scale) (5-points scale)
	Site sanitary	Site sanitary ERUL (years), Site sanitary condition rating (5-points scale)
	Plumbing fixtures	Plumbing fixtures ERUL (years), Plumbing fixtures condition rating (5-points scale)
	Water service piping	Water service piping ERUL (years), Water service piping condition rating (5-points scale), Piping material (Copper, Galvanized, PVC, Other)
Environment, Comfort, and Health ($n = 8$)	Acoustics	Noise in classrooms that impacts education (Binary)
	Flooring	Carpet ERUL (years), Carpet condition rating (3-points scale)
	Lighting	Lighting fixtures ERUL (years), Lighting fixtures condition rating (5-poiints scale), Lighting quality condition rating (3-points scale)
	Maintenance quality	3-points scale: Cleanliness condition rating, General appearance condition rating
Indoor Air Quality (IAQ) ($n = 13$)	Pest management	Binary variables: Integrated Pest Management (IPM) program, Pesticides used on the grounds, Pesticides used in the building, Certified pesticide applicator on staff, Vegetation kept one foot from building
	Radon	Binary variables: Passive radon mitigation system installed, Building tested for radon <4 pCi/L
	Ventilation and moisture	3-points scale variables: Air filters condition rating, IAQ/ventilation condition rating, Humidity/moisture condition rating
	Mold risk surfaces	Mold surfaces: (Paper-faced/gypsum, Cellulose/ceiling tile, Not applicable)

associated with older buildings lacking subsystem documentation rather than occurring at random, so listwise deletion was applied rather than imputation to avoid bias from structurally absent characteristics (Graham, 2009).

Multicollinearity was assessed using Variance Inflation Factors (VIFs), and features with VIFs> 10 were removed (Hair *et al.*, 2010). Racial and ethnic composition variables (White%, Black%, Hispanic%, Asian%) were retained despite VIFs exceeding 10 because omitting them would remove a substantively important dimension of neighborhood context consistently linked to attendance disparities (Gottfried, 2014). The resulting multicollinearity inflates the standard errors of these individual SES coefficients, so their point estimates should not be interpreted as stable independent effects. Among building-feature variables, elevated VIFs were limited to one-hot encoded indicators of mold surface materials (VIF = 19.1–23.4), which is a structural artifact of dummy coding a single categorical variable rather than a substantive collinearity concern; all other building-feature VIFs remained below 6.2.

The building component features were classified into five thematic categories: (1) Foundational Building Characteristics, (2) Building Envelope Integrity, (3) Utility Systems and Infrastructure, (4) Environment, Comfort, and Health, and (5) Indoor Air Quality (IAQ). Table 1 summarizes these categories and their constituent features.

3.3 Statistical analysis

A bivariate statistical framework was used to assess the unadjusted association between each building feature and chronic absenteeism, with test selection guided by variable type. Binary features were assessed using Welch's independent-samples *t*-tests, reporting Cohen's d as the effect-size measure with conventional thresholds of 0.20 (small), 0.50 (medium), and 0.80 (large) (Cohen, 2013). Continuous variables such as building age and square footage were evaluated using Pearson correlation coefficients (r). Ordinal Likert-scale features were tested using Spearman's rank-order correlation (ρ) to respect the ordinal structure of the data (Spearman, 1904). Multiple-choice categorical features encoded as one-hot binary indicators (e.g. water-service piping type) were analyzed using independent *t*-tests comparing buildings with versus without each option.

Because multiple features were tested within each building component category, Bonferroni correction was applied to control the family-wise error rate (Dunn, 1961). Without correction, simultaneous testing of numerous features inflates the probability of spurious significant results well beyond the nominal α level (Bland and Altman, 1995). Bonferroni correction divides the significance threshold by the number of tests within each family, strictly bounding the family-wise Type I error rate. This conservative approach was preferred over less stringent alternatives such as the Benjamini–Hochberg false discovery rate procedure (Benjamini and Hochberg, 1995), as the policy relevance of the findings warranted minimizing false positives that could misdirect limited facility investment resources. All reported *p*-values in both the bivariate analysis and the subsequent regression models are Bonferroni-adjusted. Statistical significance was defined as Bonferroni-adjusted $p < 0.05$ throughout.

Additionally, multiple linear regression (MLR) models were estimated using ordinary least squares (OLS) with HC3 heteroscedasticity-consistent robust standard errors to ensure valid inference in the presence of heteroscedasticity (MacKinnon and White, 1985). First, an SES-only model regressed chronic absenteeism on all SES variables simultaneously, quantifying their joint explanatory power. Subsequently, for each of the five building-feature categories, a separate MLR included the category's building component features alongside all SES variables as controls. Building-feature coefficients thus represent SES-adjusted effects: the estimated percentage-point change in chronic absenteeism per unit increase, holding all other variables constant. Bonferroni-adjusted *p*-values are reported for all coefficients. To systematically differentiate independent facility effects from socioeconomics, findings were interpreted with a four-case framework (robust, confounded, suppressed, and null) based on significance retention between the unadjusted bivariate and SES-controlled regression models.

To address model-stability concerns, we examined multicollinearity using VIFs and interpreted coefficients with elevated VIFs cautiously. As a robustness check, the SES-only model was re-estimated after excluding high-VIF racial and ethnic composition variables, and the direction, magnitude, and significance of the income and renter-proportion coefficients remained stable. Potential variation by urban–rural context, grade span, or district fiscal capacity was not formally tested because several building-feature subgroups had limited sample sizes, and these subgroup effects should be examined in future work.

4. Results

4.1 Socioeconomic status

The census block groups in which school buildings are located had a mean household income of 117,726 (SD = 69,784) and a mean renter proportion of 29.07% (SD = 24.89%). Additional demographic characteristics included a mean female proportion of 51.04% (SD = 7.47%), a single-parent proportion of 52.86% (SD = 34.70%), and racial/ethnic composition characterized by White (Mean = 72.70%, SD = 26.31%), Black (Mean = 9.72%, SD = 17.56%), Hispanic (Mean = 9.90%, SD = 11.73%), and Asian (Mean = 3.89%, SD = 7.37%). The share of adults holding a bachelor's degree or higher averaged 35.29% (SD = 18.81%). These figures indicate substantial socioeconomic variation across the sample, reflecting the diversity of communities served by New York State public schools.

A multiple linear regression model examining all factors as joint factors of chronic absenteeism rate was statistically significant ($F(9,452) = 28.53$, $p < 0.001$, $R^2 = 0.40$). Two of the SES variables were independently significant: Mean household income was negatively associated with chronic absenteeism ($b = -0.0001$, $p < 0.001$), indicating that school buildings in higher-income census block groups tended to have lower chronic absenteeism rates. Renter proportion was positively associated ($b = 16.44$, $p < 0.001$), indicating that areas with a greater share of renter-occupied housing had higher absenteeism. The remaining variables were not independently significant, though they may contribute jointly to the model. Full regression results are presented in Table 2. All SES variables are included as controls in all subsequent building-characteristic models to isolate the independent contributions of building component features to chronic absenteeism.

4.2 Foundational building characteristics

Foundational Building Characteristics provide context for understanding the baseline conditions and structural attributes of the school facilities (Table 3). Schools that underwent renovations or construction in the past 12 months ($N = 233$) had a mean chronic absenteeism rate of 19.04% (SD = 11.74%), compared with 26.83% (SD = 19.68%) for those without recent investment ($N = 229$), representing a medium effect size ($d = -0.48$, $p < 0.001$). Building size indicators, including square footage ($r = 0.16$, $p = 0.002$), number of floors ($r = 0.23$, $p < 0.001$), and number of instructional classrooms ($r = 0.14$, $p = 0.01$), were all positively correlated with absenteeism. Building age ($r = 0.005$, $p = 1.00$) and the overall building rating ($\rho = -0.001$, $p = 1.00$) showed no significant bivariate associations.

The SES-controlled regression model presented in Table 4 for foundational building features was statistically significant ($F(15,446) = 26.44$, $p < 0.001$, $R^2 = 0.49$). Two building features showed significant independent associations. The recent renovation remained significant ($b = -5.54$, $p < 0.001$), confirming a robust, SES-independent relationship:

Table 2. Multivariable regression associations between socioeconomics and chronic absenteeism across school buildings

Feature	Coefficient (β)	SE	*p*-value
Mean Household Income ($)	−0.0001***	0.00	<0.001
Bachelor's Degree or Higher (%)	−1.00	7.94	1.00
Renter (%)	16.44***	4.19	<0.001
Female (%)	−17.32	16.45	1.00
Single Parent (%)	−0.82	1.96	1.00
Asian (%)	−11.70	12.79	1.00
Black (%)	17.62	11.07	1.00
White (%)	−4.94	9.90	1.00
Hispanic (%)	0.26	11.11	1.00

Table 3. Associations between foundational building characteristics and chronic absenteeism across school buildings

Feature	*N*	Stats	Method	Statistics	*p*-value
Renovations in the past 12 months?	462	Yes($N = 233$): 19.04 ± 11.74% No ($N = 229$): 26.83 ± 19.68%	*t*-test	d = −0.48***	<0.001
Building Age (years)	462	Mean = 73.29 ± 41.30	Pearson	r = −0.005	1.00
Square feet of construction	462	Mean = 77053.58 ± 63062.82	Pearson	r = 0.16**	0.002
Number of Floors	455	Mean = 2.03 ± 0.86	Pearson	r = 0.23***	<0.001
Number of instructional classrooms	462	Mean = 37.95 ± 22.88	Pearson	r = 0.14*	0.01
Overall building rating (4-point scale)	461	Mean = 2.96 ± 0.32	Spearman	ρ = −0.004	1.00

Note(s): Stats for binary features show Absence Mean and Absence SD. For continuous features, Stats displays the feature itself, along with Mean ± SD. For ordinal features, Stats displays the feature itself, along with Mean ± SD. d = Cohen's d. r = Pearson's r. ρ = Spearman's rho. Bonferroni-adjusted Significance levels: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Table 4. Multivariable regression associations between foundational building characteristics and chronic absenteeism across school buildings

Feature	Coefficient (β)	SE	*p*-value
Mean Household Income ($)	−0.0001***	0.00	<0.001
Bachelor's Degree or Higher %	−4.21	6.44	1.00
Renter %	16.77***	3.83	<0.001
Female %	−14.30	12.78	1.00
Single Parent %	−0.84	1.86	1.00
Asian %	−13.78	11.96	1.00
Black %	21.15	8.72	0.230
White %	−0.50	8.28	1.00
Hispanic %	0.18	9.32	1.00
Renovations in the past 12 months?	−5.54***	1.17	<0.001
Building Age (years)	0.01	0.03	1.00
Square feet of construction	0.00002	0.00002	1.00
Number of Floors	0.42	0.74	1.00
Number of instructional classrooms	0.10	0.04	0.11
Overall building rating (4-point scale)	9.95***	1.92	<0.001

schools with recent construction had absenteeism rates approximately 5.5% points lower, even after controlling for socioeconomic context. The three building-size indicators (square footage, number of floors, number of classrooms), although significant in bivariate analysis, were not retained in the MLR model, indicating that the observed association is likely explained by underlying socioeconomic confounding factors rather than building size itself; that is, larger school buildings tend to be located in urban, lower-income communities with higher baseline absenteeism.

A notable suppression effect emerged for the overall building rating (4 = Excellent, 3 = Good, 2 = Fair, 1 = Poor), which showed no bivariate association ($\rho = -0.004$, $p = 1.00$) but became a significant positive predictor in the regression model ($b = 9.95$, $p < 0.001$). This pattern suggests that in bivariate analysis, the positive association was obscured by the correlation between building ratings and SES: buildings in wealthier communities tend to receive higher ratings and have lower absenteeism, offsetting the independent association. Once socioeconomic factors were controlled, a positive association emerged. This sign reversal is consistent with a suppression interpretation in which ratings capture cosmetic rather than health-relevant quality: among schools with similar SES profiles, those with higher overall ratings had higher absenteeism, potentially because favorable visual assessments do not reflect indoor environmental hazards such as pesticide use or mold-susceptible materials. However, alternative statistical explanations cannot be excluded, including residual confounding from unmeasured SES dimensions, collider bias introduced by conditioning on correlated SES controls, or instability in coefficient estimates due to elevated VIFs among the racial composition variables. This finding should therefore be treated as exploratory rather than confirmatory. Building age showed no significant association in either analysis ($r = -0.005$, $p = 1.00$; $b = 0.01$, $p = 1.00$), suggesting that system condition and maintenance are more closely associated with absenteeism than building age.

4.3 Building envelope

Bivariate results (Table 5) identified two significant associations. The presence of chimneys showed a large effect ($d = -1.11$, $p < 0.001$): buildings with chimneys had a mean absenteeism rate of 20.56% (SD = 14.25%) versus 37.74% (SD = 22.14%) without. Chimneys' expected remaining useful lifetime (ERUL) was positively correlated with absenteeism ($r = 0.23$, $p = 0.02$). Window and skylight measures (presence, ERUL, condition) were not significant after correction.

The SES-controlled regression for building envelope presented in Table 6 was statistically significant ($F(18,227) = 9.56$, $p < 0.001$, $R^2 = 0.46$). The smaller sample results from listwise deletion of buildings with incomplete data for all envelope components. The main reason for case loss was missing chimney ERUL data among buildings that have chimneys but lack documented longevity estimates. To evaluate potential selection bias, the 246 included buildings were compared with the 216 excluded ones. The included sample had significantly higher average absenteeism compared to the excluded group (27.22% vs 17.98%, $p < 0.001$). The included buildings also showed lower average household income (106,008 vs 131,072; $p < 0.001$), higher renter proportions (35% vs 22%; $p < 0.001$), higher Black population

Table 5. Associations between building envelope characteristics and chronic absenteeism across school buildings

Feature	*N*	Stats	Method	Statistics	*p*-value
Chimneys	462	Yes($N = 399$): 20.56 ± 14.25% No($N = 63$): 37.74 ± 22.14%	*t*-test	d = −1.11***	<0.001
Chimneys ERUL	209	16.54 ± 8.88	Pearson	r = 0.23*	0.02
Chimneys Condition (5-point scale)	399	3.96 ± 0.27	Spearman	ρ = 0.01	1.00
Windows	462	Yes($N = 459$): 22.83 ± 16.63% No ($N = 3$): 33.37 ± 11.84%	*t*-test	d = −0.63	1.00
Windows ERUL	459	10.94 ± 7.04	Pearson	r = 0.10	0.26
Windows Condition (5-point scale)	459	3.96 ± 0.35	Spearman	ρ = 0.04	1.00
Skylights	461	Yes($N = 261$): 21.66 ± 14.37% No($N = 200$): 24.57 ± 19.09%	*t*-test	d = −0.18	0.65
Skylights ERUL	261	12.00 ± 8.32	Pearson	r = 0.05	1.00
Skylights Condition (5-point scale)	195	4.00 ± 0.28	Spearman	ρ = −0.08	1.00

Table 6. Multivariable regression associations between building envelope characteristics and chronic absenteeism across school buildings

Feature	Coefficient (β)	SE	*p*-value
Mean Household Income ($)	−0.0001*	0.00003	0.01
Bachelor's Degree or Higher %	12.64	11.03	1.00
Renter %	11.76	6.24	1.00
Female %	−21.75	20.51	1.00
Single Parent %	−2.72	2.95	1.00
Asian %	−53.70	25.21	0.60
Black %	−29.15	23.15	1.00
White %	−59.49	21.82	0.12
Hispanic %	−47.08	22.74	0.69
Chimneys	−21.86	18.65	1.00
Chimneys ERUL	0.46*	0.15	0.04
Chimneys Condition (5-point scale)	2.90	4.78	1.00
Windows	−39.86	13.42	0.05
Windows ERUL	0.12	0.16	1.00
Windows Condition (5-point scale)	8.81*	2.89	0.04
Skylights	32.42	15.51	0.66
Skylights ERUL	0.08	0.15	1.00
Skylights Condition (5-point scale)	−8.20	3.96	0.70

percentages (13% vs 6%; $p < 0.001$), and lower White population percentages (69% vs 77%; $p = 0.002$). These differences suggest that the analytic sample for the envelope category is biased toward more socioeconomically disadvantaged, higher-absenteeism buildings, which should be considered when interpreting the regression results.

Two building features demonstrated significant, independent associations. Chimneys ERUL remained significant ($b = 0.46$, $p = 0.04$), indicating that each additional year of expected remaining chimney life was associated with a 0.46-percentage-point higher chronic absenteeism rate, independent of SES. The presence of chimneys, although strongly significant in bivariate analysis, became nonsignificant after SES adjustment ($b = -21.86$, $p = 1.00$), suggesting that the bivariate association was confounded by socioeconomic differences between buildings with and without chimneys.

Windows condition exhibited a suppression pattern similar to the overall building rating in Section 4.2: nonsignificant in bivariate analysis ($\rho = 0.04$, $p = 1.00$) but significant in regression ($b = 8.81$, $p = 0.04$). After adjusting for SES and other covariates, a higher inspector-rated window condition was associated with higher absenteeism. Like the building rating result, this result is consistent with the interpretation that visual condition scores capture surface-level appearance rather than health-relevant performance (e.g. airtightness, ventilation adequacy). However, the same alternative statistical explanations remain; residual confounding, collider bias, and VIF-related coefficient instability cannot be ruled out. This finding should be treated as exploratory. Skylights showed no evidence of independent association.

4.4 Utility systems and infrastructure

Bivariate analyses of the utility-system features (Table 7) identified four significant associations after Bonferroni correction. Three were positively correlated with absenteeism: site gas ERUL (Mean = 16.54, SD = 8.79, r = 0.20, $p < 0.001$), site sanitary ERUL (Mean = 14.86, SD = 9.22, r = 0.15, $p = 0.01$), and water service piping ERUL (Mean = 15.93, SD = 11.03, r = 0.14, $p = 0.02$). Buildings with copper water piping had significantly lower absenteeism than those without (d = −0.58, $p < 0.001$; 17.80% vs 27.12%). Copper pipes offer antimicrobial properties, greater corrosion resistance, and

Table 7. Associations between utility systems characteristics and chronic absenteeism across school buildings

Feature	*N*	Mean ± SD	Method	Statistics	*p*-value
Site Gas ERUL	437	16.53 ± 8.79	Pearson	r = 0.20***	<0.001
Site Gas Condition (5-point scale)	437	4.03 ± 0.21	Spearman	ρ = −0.05	0.32
Site Sanitary ERUL	460	14.86 ± 9.22	Pearson	r = 0.15*	0.001
Site Sanitary Condition (5-point scale)	460	4.00 ± 0.25	Spearman	ρ = 0.04	0.38
Plumbing Fixtures ERUL	461	12.32 ± 9.52	Pearson	r = 0.10	0.03
Plumbing Fixtures Condition (5-point scale)	461	3.98 ± 0.28	Spearman	ρ = −0.08	0.10
Water Service Piping ERUL	462	15.93 ± 11.03	Pearson	r = 0.14*	0.002
Water Service Piping Condition (5-point scale)	462	4.00 ± 0.15	Spearman	ρ = 0.03	0.57
Water Service Piping Type – Copper	462	Yes(*N* = 209): 17.80 ± 12.82% No(*N* = 253): 27.12 ± 18.16%	*t*-test	d = −0.58***	<0.001
Water Service Piping Type – Galvanized	462	Yes(*N* = 83): 22.72 ± 12.70% No(*N* = 379): 22.94 ± 17.37%	*t*-test	d = −0.01	1.00
Water Service Piping Type – PVC	462	Yes(*N* = 26): 21.71 ± 9.37% No(*N* = 436): 22.97 ± 16.95%	*t*-test	d = −0.08	1.00
Water Service Piping Type – Other	462	Yes(*N* = 11): 26.40 ± 9.70% No(*N* = 451): 22.81 ± 16.75%	*t*-test	d = 0.22	1.00

superior prevention of lead leaching compared to other materials (WHO, 2004; Vargas *et al.*, 2017; Montero *et al.*, 2019), likely leading to safer, better-tasting water, improved student hydration, and reduced health-related absences (Sauve-Syed, 2024).

The SES-controlled regression was significant ($F(21,415) = 16.58$, $p < 0.001$, $R^2 = 0.47$). However, after Bonferroni correction, no utility-system features retained independent significance (Table 8). All four features that were significant in the bivariate analysis, including the three ERUL variables and Water Service Piping Copper Type, became nonsignificant when SES was controlled. This indicates that the bivariate associations observed for utility-system features were largely confounded by socioeconomic factors. Among the SES controls, mean household income and renter proportion remained significant.

4.5 Environment, comfort, and health

The bivariate results show no significant association between absenteeism and perceived cleanliness, lighting, appearance, or acoustics (Table 9). Only carpet-related measures were significant: better carpet condition is associated with lower absenteeism (Mean = 3.96, SD = 0.30, $\rho = -0.13$, $p = 0.04$), consistent with evidence that poorly maintained carpets resuspend dust and bio-contaminants and exacerbate respiratory issues (Becher *et al.*, 2018). Conversely, higher carpet ERUL was weakly associated with absenteeism ($r = 0.14$, $p = 0.04$; Mean = 8.14, SD = 4.78), indicating that schools with higher carpet ERUL values tend to have slightly higher absenteeism rates. Newly installed or long-life carpets are a well-documented source of indoor air quality concern, in building materials research (Jarnstrom *et al.*, 2006), particularly during the early years following installation (Wei *et al.*, 2019).

Table 8. Multivariable regression associations between utility systems and chronic absenteeism across school buildings

Feature	Coefficient (β)	SE	*p*-value
Mean Household Income ($)	−0.0001**	0.00002	0.001
Bachelor's Degree or Higher %	−0.53	7.59	1.00
Renter %	15.23**	4.03	0.003
Female %	−15.81	15.67	1.00
Single Parent %	−0.67	2.06	1.00
Asian %	−11.54	12.62	1.00
Black %	21.98	10.80	0.88
White %	−4.54	9.82	1.00
Hispanic %	−1.34	10.92	1.00
Site Gas ERUL	0.27	0.09	0.06
Site Gas Condition (5-point scale)	−2.66	1.90	1.00
Site Sanitary ERUL	0.02	0.09	1.00
Site Sanitary Condition (5-point scale)	−0.99	3.88	1.00
Plumbing Fixtures ERUL	4.60	2.03	0.49
Plumbing Fixtures Condition (5-point scale)	0.08	0.08	1.00
Water Service Piping ERUL	0.07	0.06	1.00
Water Service Piping Condition (5-point scale)	3.15	3.71	1.00
Water Service Piping Type – Copper	−3.24	1.35	0.34
Water Service Piping Type – Galvanized	−3.23	1.75	1.00
Water Service Piping Type – PVC	−1.52	2.44	1.00
Water Service Piping Type – Other	2.93	3.58	1.00

Table 9. Associations between environment, comfort, and health characteristics and chronic absenteeism across school buildings

Feature	*N*	Stats	Method	Statistics	*p*-value
Noise in classrooms that impacts education	462	Yes ($N = 31$): 19.32 ± 15.11% No ($N = 431$): 23.16 ± 16.70%	*t*-test	d = −0.23	1.00
Carpet ERUL	433	8.14 ± 4.78	Pearson	r = 0.14*	0.04
Carpet Condition (3-point scale)	433	3.96 ± 0.30	Spearman	ρ = −0.13*	0.04
Lighting Fixtures ERUL	460	11.38 ± 6.87	Pearson	r = 0.03	1.00
Lighting Fixtures Condition (5-point scale)	458	4.05 ± 0.35	Spearman	ρ = 0.01	1.00
Lighting Quality Condition (3-point scale)	462	2.66 ± 0.51	Spearman	ρ = −0.03	1.00
Cleanliness Condition (3-point scale)	462	2.89 ± 0.31	Spearman	ρ = 0.01	1.00
General Appearance Condition (3-point scale)	462	2.83 ± 0.38	Spearman	ρ = 0.05	1.00

Identified emissions can degrade indoor air quality and contribute to respiratory symptoms (Hodgson *et al.*, 1993). This provides a plausible mechanistic basis for the observed positive association between carpet ERUL and absenteeism, though this interpretation remains exploratory in the absence of direct VOC measurements.

The SES-controlled regression was significant ($F(17,409) = 18.46$, $p < 0.001$, $R^2 = 0.43$), but no features maintained independent significance (Table 10). Both carpet variables, which were significant in the bivariate analysis, became nonsignificant after SES adjustment (carpet ERUL: $b = 0.39$, $p = 0.16$; carpet condition: $b = -3.11$, $p = 1.00$), suggesting that

Table 10. Multivariable regression associations between environment, comfort, and health characteristics and chronic absenteeism across school buildings

Feature	Coefficient (β)	SE	*p*-value
Mean Household Income ($)	−0.0001***	0.00002	<0.001
Bachelor's Degree or Higher %	−2.23	8.06	1.00
Renter %	15.90**	4.17	0.002
Female %	−12.52	16.45	1.00
Single Parent %	−1.60	2.07	1.00
Asian %	−4.83	12.70	1.00
Black %	22.82	10.68	0.55
White %	−1.45	9.49	1.00
Hispanic %	8.20	10.48	1.00
Noise in classrooms that impacts education	−2.18	2.51	1.00
Carpet ERUL	0.39	0.15	0.16
Carpet Condition (3-point scale)	−3.11	2.20	1.00
Lighting Fixtures ERUL	0.01	0.10	1.00
Lighting Fixtures Condition (5-point scale)	2.67	1.54	1.00
Lighting Quality Condition (3-point scale)	2.78	1.23	0.40
Cleanliness Condition (3-point scale)	−0.45	3.19	1.00
General Appearance Condition (3-point scale)	3.72	2.64	1.00

socioeconomic factors confounded the results. The null findings for lighting quality (ρ = −0.03, p = 1.00; b = 2.78, p = 0.40), cleanliness (ρ = 0.01, p = 1.00; b = −0.45, p = 1.00), and overall appearance (ρ = 0.05, p = 1.00; b = 3.72, p = 1.00) are consistent across both analysis and should be cautious: these ordinal ratings showed very limited variance (e.g. cleanliness: Mean = 2.89, SD = 0.31), which restricts the statistical power to detect possible associations.

4.6 Indoor air quality

The IAQ category produced the most findings. Bivariate results (Table 11) identified significant features including indoor pesticide use (d = 0.77, $p < 0.001$) and outdoor pesticide use (d = −0.33, $p < 0.001$), vegetation maintenance distance (d = 0.34, $p < 0.001$), radon testing below 4 pCi/L (d = −0.31, p = 0.001), passive radon mitigation (d = −0.68, $p < 0.001$), and mold-susceptible surface materials, as paper-faced/gypsum products (d = 0.39, $p < 0.001$), cellulose/ceiling products (d = 0.34, p = 0.004). The inspector-rated conditions (air filters, IAQ/ventilation, humidity/moisture) were not significant.

The SES-controlled regression (Table 12; F(22,436) = 23.79, $p < 0.001$, $R^2 = 0.54$, N = 459) achieved the highest explanatory power across all categories. Several features lost statistical significance after SES adjustment, indicating that their bivariate associations were largely explained by underlying socioeconomic differences. The three inspector-rated IAQ metrics (air filters, IAQ/ventilation, humidity/moisture) showed no evidence of association in either set of results. The null result for the condition may reflect the limited variance in inspector ratings rather than the absence of a true relationship, as air filtration effectiveness depends on factors (e.g. filter type, replacement frequency) not captured by ordinal condition scores.

4.6.1 Pesticides management. School buildings that use pesticides on their grounds have an average absenteeism rate of 18.19%, which is 5.53% points lower than the rate for buildings that do not use pesticides (d = −0.33, p = 0.01). In contrast, indoor pesticide use showed a large effect (d = 0.77, $p < 0.001$): buildings with indoor pesticide application had an absenteeism rate of 30.27% (SD = 21.76%), compared to 18.32% (SD = 9.98%) in buildings without indoor pesticide application. After controlling for SES, indoor pesticide use remained the strongest positive association (b = 8.09, $p < 0.001$): buildings with indoor pesticide

Table 11. Associations between indoor air quality characteristics and chronic absenteeism across school buildings

Feature	N	Stats	Method	Statistics	p-value
Integrated Pest Management (IPM)	462	Yes ($N = 382$): 23.14 ± 17.17% No ($N = 80$): 21.75 ± 13.68%	t-test	d = 0.08	1.00
Pesticides are used on the grounds	462	Yes ($N = 68$): 18.19 ± 7.82% No ($N = 394$): 23.71 ± 17.57%	t-test	d = −0.33***	<0.001
Pesticides used in the building	462	Yes ($N = 177$): 30.27 ± 21.76% No ($N = 285$): 18.32 ± 9.98%	t-test	d = 0.77***	<0.001
A certified pesticide applicator is on staff	462	Yes ($N = 76$): 19.71 ± 10.51% No ($N = 386$): 23.53 ± 17.51%	t-test	d = −0.23	0.15
Vegetation kept one foot away from the building	462	Yes ($N = 358$): 24.16 ± 18.00% No ($N = 104$): 18.58 ± 9.37%	t-test	d = 0.34***	<0.001
A passive radon mitigation system was installed	462	Yes ($N = 19$): 12.23 ± 7.93% No ($N = 443$): 23.36 ± 16.74%	t-test	d = −0.68***	<0.001
Building tested for radon <4 pCi/L	459	Yes ($N = 108$): 19.04 ± 9.02% No ($N = 351$): 24.21 ± 18.18%	t-test	d = −0.31**	0.001
Air filters Condition (3-point scale)	462	2.68 ± 0.47	Spearman	ρ = 0.09	0.62
IAQ/Ventilation Condition (3-point scale)	462	2.66 ± 0.54	Spearman	ρ = 0.09	0.82
Humidity/Moisture Condition (3-point scale)	462	2.71 ± 0.47	Spearman	ρ = 0.04	1.00
Mold Surfaces Materials - Paper-faced/Gypsum	462	Has($N = 372$): 23.99 ± 17.45% No($N = 90$): 18.39 ± 11.62%	t-test	d = 0.34**	0.004
Mold Surfaces Materials – Cellulose/Ceiling	462	Yes($N = 327$): 24.77 ± 18.18% No($N = 135$): 18.38 ± 10.79%	t-test	d = 0.39***	<0.001
Mold Surfaces Materials – Not Applicable	462	Has($N = 75$): 18.76 ± 12.14% No($N = 387$): 23.70 ± 17.25%	t-test	d = −0.30*	0.04

application had absenteeism roughly 8.1% points higher, while holding SES constant. Outdoor pesticide use also remained negatively associated with absenteeism ($b = -4.86$, $p = 0.02$). The contrasting directions of the indoor and outdoor associations may reflect differences in underlying facility management contexts and provide a direction for future pest management use; however, the cross-sectional design limits causal interpretation.

4.6.2 Vegetation. Schools where vegetation was maintained at least one foot away from the building ($N = 358$) had a mean chronic absenteeism rate of 24.16% (SD = 18.00%), compared

Table 12. Multivariable regression associations between indoor air quality characteristics and chronic absenteeism across school buildings

Feature	Coefficient (β)	SE	*p*-value
Mean Household Income ($)	−0.0001***	0.00002	<0.001
Bachelor's Degree or Higher %	−1.63	6.71	1.00
Renter %	13.00**	3.55	0.01
Female %	−14.16	13.68	1.00
Single Parent %	−0.04	1.86	1.00
Asian %	−17.68	12.25	1.00
Black %	15.93	10.14	1.00
White %	−6.21	9.16	1.00
Hispanic %	−5.46	10.19	1.00
Integrated Pest Management (IPM)	−0.21	1.49	1.00
Pesticides are used on the grounds	−4.86*	1.48	0.02
Pesticides used in the building	8.09***	1.43	<0.001
A certified pesticide applicator is on staff	0.63	1.42	1.00
Vegetation kept one foot away from the building	1.92	1.19	1.00
A passive radon mitigation system was installed	−3.46	2.75	1.00
Building tested for radon <4 pCi/L	−4.14*	1.34	0.04
Air filters Condition (3-point scale)	1.56	1.59	1.00
IAQ/Ventilation Condition (3-point scale)	1.69	1.52	1.00
Humidity/Moisture Condition (3-point scale)	2.82	1.28	0.60
Mold Surfaces Materials - Paper-faced/Gypsum	7.30	2.59	0.11
Mold Surfaces Materials – Cellulose/Ceiling	6.57***	1.52	<0.001
Mold Surfaces Materials – Not Applicable	10.49*	3.29	0.03

to 18.58% (SD = 9.37%) in schools where vegetation grew closer to the façade without maintenance at this distance ($N = 104$). This reflects a small-to-moderate effect size (d = 0.34, $p < 0.001$). One possible explanation is that vegetation along the façade may enhance local microenvironmental conditions by intercepting airborne particulates and moderating temperature extremes (Diener and Mudu, 2021), as well as providing restorative natural views linked to reduced stress and improved well-being (Tyrväinen *et al.*, 2014). However, after adjusting for socioeconomic factors, this association was no longer statistically significant ($b = 1.92$, $p = 1.00$), indicating that the initial correlation was confounded by SES-related differences. Schools with vegetation closer to the building are likely situated in suburban or more affluent communities where lower-density development allows for closer landscaping, and where baseline absenteeism tends to be lower due to socioeconomic advantages.

4.6.3 Radon management. The presence of a passive radon mitigation system was associated with a moderate decrease in absenteeism, with a 11.13-point lower rate (d = −0.68, $p < 0.001$); however, this should be interpreted with caution due to the limited sample size ($N = 19$), which reduces statistical power and reliability. Schools that had radon testing below 4 pCi/L also had a 5.17-point lower absenteeism rate (d = −0.31, $p = 0.005$). In controlled MLR, radon testing remained significant ($b = -4.14$, $p = 0.04$), suggesting that proactive environmental monitoring is independently associated with lower absenteeism. However, the presence of a passive radon mitigation system lost significance ($b = -3.46$, $p = 1.00$), a pattern consistent with confounding: the small number of schools with passive systems may be concentrated in specific districts with distinctive socioeconomic profiles.

4.6.4 Materials. Mold surface materials results indicate that the presence of mold-susceptible materials, paper-faced or gypsum products (drywall), and cellulose products (ceiling tiles), is associated with higher absenteeism (d = 0.39, $p < 0.001$; d = 0.34, $p = 0.004$, respectively). This is consistent with the documented mold-absenteeism pathway: gypsum boards with cellulosic paper are prone to fungal growth, which has been linked to structural degradation and risks such as sick building syndrome (Kazemian *et al.*, 2019). Visible mold in schools has been associated with higher absenteeism through worsened respiratory symptoms, such as asthma (Simons *et al.*, 2010). In the SES-controlled model, cellulose/ceiling products retained a robust positive association ($b = 6.57$, $p < 0.001$), suggesting an independent association with absenteeism. Paper-faced/gypsum surfaces became nonsignificant after SES adjustment ($b = 7.30$, $p = 0.11$), suggesting that their presence covaries with neighborhood contexts' disadvantage.

4.6.5 IAQ conditions. The three inspector-rated IAQ metrics (air filters, IAQ/ventilation, humidity/moisture) showed no evidence of association in either set of results. Bivariate correlations were extremely weak (all $\rho \leq 0.09$; $p > 0.05$), and all three metrics remained nonsignificant after SES adjustment (all $p \geq 0.60$; full coefficients in Table 12). These consistent null results likely reflect severe range restriction on the 3-point evaluation scale, where scores cluster near the maximum and standard deviations are small, attenuating statistical power. The pattern also suggests that static visual ratings do not capture the operational characteristics most relevant to IAQ outcomes (e.g. filter type, replacement frequency, real-time ventilation performance), which the literature identifies as the dimensions most strongly associated with student attendance (Mendell *et al.*, 2013).

5. Discussion

This study's findings provide a granular, component-level understanding of the complex relationship between the physical school environment and chronic student absenteeism.

5.1 The confounding role of socioeconomic context

The most important finding is the dominant role of community socioeconomic context. The SES-only model explained 40% of the variance in chronic absenteeism, indicating that neighborhood-level income and housing tenure are stronger correlates of student attendance than any single physical building feature. This is consistent with the broader literature, which recognizes poverty, family instability, and community disadvantage as primary correlates of educational disengagement (Balfanz and Byrnes, 2012). More critically, over half of the building features that appeared significant in the bivariate results, including building size indicators, copper water piping, carpet condition, and several utility-system metrics, lost significance once SES was controlled. This pattern demonstrates a pervasive confounding structure: physically deteriorated buildings are concentrated in socioeconomically disadvantaged communities, and what appears to be a "building effect" is, in many cases, a neighborhood effect.

The finding about copper piping shows this clearly. In a bivariate analysis, buildings with copper piping were associated with lower absenteeism, suggesting policy recommendations for pipe replacement. However, after adjusting for SES, this association disappeared, suggesting that copper piping reflects community wealth and building investment rather than an independent factor related to student absenteeism. This highlights the risk of making policy decisions based on unadjusted cross-sectional observational data and validates the importance of including SES controls in all regression models.

5.2 Renovation and maintenance

Recent renovation emerged as an SES-independent building-level correlate of lower absenteeism. Importantly, building age itself showed no association in either analysis. Together, these findings suggest that it is not how old a school is that is associated with absenteeism, but whether it has been actively maintained and renovated. This is consistent with the evidence that buildings with adequate structural life may still have deteriorated indoor environments when preventive maintenance is neglected (Lavy and Bilbo, 2009).

However, the association between renovation and absenteeism should be interpreted with two caveats. First, recent renovation may partly proxy for district-level funding capacity rather than building quality alone (Lafortune and Schönholzer, 2017). Because school capital funding relies heavily on local wealth, districts with greater fiscal resources are more likely to undertake facility renovations (Filardo, 2021). These well-resourced districts also tend to serve wealthier communities with lower baseline absenteeism (Sosu *et al.*, 2021; Chang, 2025), meaning that residual confounding by unmeasured dimensions of district fiscal health cannot be fully excluded despite the nine SES controls. Second, the cross-sectional design cannot establish whether renovation precedes attendance improvement or whether districts with improved attendance are more likely to invest in facilities. Longitudinal or quasi-experimental designs, such as those exploiting the timing of bond-funded renovation programs (Cellini *et al.*, 2010), would be needed to assess directionality. From a policy perspective, the results are consistent with prioritizing renovation of existing stock rather than privileging new construction, though formal cost-effectiveness analysis would be required.

5.3 Indoor air quality: pesticides, radon, and mold

The IAQ category produced the most numerous and strongest independent associations, consistent with a well-established body of evidence linking indoor environmental exposures to respiratory health and school attendance (Mendell and Heath, 2005; Mendell *et al.*, 2011).

Indoor pesticide application was associated with substantially higher absenteeism, aligning with prior work on chemical exposure pathways in school settings (Gilliland *et al.*, 2001). Outdoor pesticide use, by contrast, was associated with lower absenteeism. The contrasting directions of the indoor and outdoor associations may reflect differences in underlying facility management contexts: indoor application may reflect reactive responses to existing pest infestations, whereas outdoor application may reflect more common preventive practices in better-resourced schools. However, the cross-sectional design limits the ability to establish directionality between these practices. This distinction is notable because it separates IAQ from other categories (e.g. utility systems, building size) in which bivariate associations were largely explained by socioeconomic confounding.

Radon testing below the EPA threshold was also associated with lower absenteeism, suggesting that proactive environmental monitoring may serve as a marker of broader institutional commitment to indoor environmental quality rather than a direct health pathway.

Similarly, among mold-related variables, the presence of cellulose/ceiling products remained positively associated with absenteeism, consistent with epidemiological evidence linking dampness, mold, and mold-susceptible materials to asthma and respiratory illness (Mendell *et al.*, 2011; Kazemian *et al.*, 2019). Paper-faced/gypsum surfaces became nonsignificant after controlling for SES, indicating that their presence covaries with socioeconomic disadvantage. Replacing ceiling materials during routine renovation cycles may represent a relatively low-cost, targeted intervention, though longitudinal evidence would be required to establish whether such changes are associated with attendance improvements.

5.4 Inspector-assessed metrics: ERUL and condition ratings

Both ERUL and inspector-rated condition ratings are subjective assessments recorded during facility walkthroughs, and their results follow a similar pattern. Multiple ERUL variables exhibited positive bivariate correlations with absenteeism, but nearly all became nonsignificant after SES adjustment, indicating socioeconomic confounding. Chimneys ERUL was the sole exception ($b = 0.46$, $p = 0.04$), but this counterintuitive result should be treated as hypothesis-generating given the cross-sectional design, the non-representative analytic sample ($N = 246$; see Section 4.3), and the possibility of residual confounding. Similarly, overall building rating and window condition exhibited suppression effects: nonsignificant in bivariate analysis but positively associated with absenteeism after SES control. As discussed in Sections 4.2 and 4.3, these sign reversals are consistent with the interpretation that visual ratings capture appearance rather than health-relevant performance, but alternative statistical explanations, including residual confounding, collider bias, and coefficient instability from elevated VIFs, cannot be excluded. All three findings should be treated as exploratory.

The broader pattern across the study supports this concern. Aggregate facility metrics generally showed no stable or directly interpretable association with absenteeism. Overall building rating and window condition became significant only after SES adjustment, but these suppression patterns were treated as exploratory because they may reflect residual confounding, collider bias, or coefficient instability rather than a clear health-relevant facility effect. Other perceived condition measures—cleanliness, lighting quality, general appearance, and the three IAQ rating items—showed no associations with absenteeism in either set of results, while component-level variables tied to specific materials, practices, and exposures (indoor pesticide use, mold-susceptible ceiling materials, radon testing) retained robust independent associations after SES adjustment. The implication is that conventional inspection protocols, which rely on visible condition and broad ordinal scales, do not consistently track the building features most relevant to student health and attendance: a building can score favorably on aggregate ratings while still harboring the IAQ exposures most strongly associated with absenteeism in this study.

These findings indicate a fundamental measurement gap in school facility assessment. Periodic walkthroughs, whether for scoring conditions or estimating system longevity, provide snapshots of visible quality but do not capture indoor environmental exposures most consistently associated with attendance in this study. Recent work demonstrates the feasibility and value of continuous, objective environmental monitoring in schools: Researchers deployed year-long CO_2 sensors across Boston Public Schools and found that real-time data revealed ventilation failures and spatial variability that periodic spot-checks would miss (Ge *et al.*, 2025), while others developed a protocol for large-scale sensor deployment across 280 classrooms in the Netherlands to objectively link IEQ to student outcomes (Palacios Temprano *et al.*, 2020). These school-specific monitoring approaches, along with emerging data-driven frameworks for building environmental assessment (Karamoozian *et al.*, 2026), advanced construction technologies that influence long-term building performance (Karamoozian and Zhang, 2026), and structured decision-making frameworks for system-level investment (Karamoozian and Hong, 2023), offer potential directions for supplementing inspector evaluations with objective, health-oriented measurements, though their integration into mandated facility condition surveys such as the BCS remains untested.

5.5 Implications for practice and policy

The applied implication is not that districts should treat every significant coefficient as a direct causal intervention. Instead, facility managers can use statistically robust and mechanistically plausible associations as a screening framework for maintenance prioritization, consistent with calls to align school facility assessment with health-relevant exposures rather than aggregate visual condition (Mendell *et al.*, 2013; Toyinbo, 2023). Routine inspections and work-order systems should prioritize observable and modifiable components aligned with the results, including indoor pesticide practices, given randomized evidence that integrated pest management can reduce asthma-related symptom days (Phipatanakul *et al.*, 2021); mold-susceptible cellulose ceiling materials, which are linked to dampness-related respiratory illness (Mendell *et al.*, 2011); radon testing status, which remains uneven across U.S. schools despite federal recommendations (Gordon *et al.*, 2018); and recent renovation or maintenance history. These items should be reviewed alongside complaints, nurse logs, IAQ records, and attendance patterns before capital decisions are made.

For capital planning, the findings support targeted renovation of existing buildings over age-based replacement alone, consistent with quasi-experimental evidence that renovation activity, rather than building age itself, drives attendance- and achievement-relevant change

(Cellini *et al.*, 2010; Lafortune and Schönholzer, 2017). District administrators can use component-level BCS data to rank projects by potential health and attendance relevance, especially in high-absenteeism schools serving socioeconomically disadvantaged communities, where capital funding gaps are typically widest (Filardo, 2021). Because the evidence is observational, priorities should be paired with follow-up evaluation, such as pre/post attendance tracking and objective IAQ monitoring (Palacios Temprano *et al.*, 2020; Ge *et al.*, 2025).

Two additional policy implications follow. First, aggregate facility ratings and inspector-rated condition scores should not be used as standalone indicators of attendance-relevant building performance because they did not track the building features most strongly associated with absenteeism; continuous IAQ instrumentation, such as CO_2 and particulate monitoring, can supplement periodic walkthroughs and reduce this measurement gap. Second, because socioeconomic context explained approximately 40% of absenteeism variance, facility investment should be treated as one component of a broader attendance strategy that also addresses health, transportation, and family engagement.

5.6 Limitations and future research directions

Several limitations arise from this study. First, given their observational, cross-sectional design, the findings reflect associations rather than causal relationships and should not serve as the sole basis for policy decisions without support from longitudinal or experimental research. Second, the building condition data relied on inspector assessments with restricted variance, which limits precision; future work would benefit from objective indoor environmental monitoring, including measurements of VOCs, particulate matter, and humidity, to better characterize occupant exposures. Third, although the analysis adjusted for nine SES variables, residual confounding likely remains, particularly from unmeasured factors such as school district policies and student health characteristics. In addition, listwise deletion reduced the analytic sample for some building categories, and the regression sample for envelope variables differed systematically from the excluded buildings on both absenteeism and SES characteristics, potentially introducing selection bias. Finally, because the study was limited to New York State, the findings may not generalize across jurisdictions with different school systems, building stock, and policy contexts. Future research should employ longitudinal or quasi-experimental designs to establish temporal precedence, incorporate objective IAQ instrumentation (continuous environmental monitoring) to validate and supplement inspector-based assessments, conduct formal cost-benefit analysis for the targeted interventions suggested by the robust associations identified here, and extend this framework to school systems with more diverse socioeconomic backgrounds in other jurisdictions across the nation.

6. Conclusion

This study linked chronic absenteeism data for New York State public school buildings with component-level building information from the 2024 Building Condition Survey, applying Bonferroni-corrected bivariate tests and socioeconomics-controlled multiple linear regression to identify which facility characteristics are independently associated with student absence.

The results point toward a coherent, if cautious, set of priorities for school facility management. Community socioeconomic context is the dominant correlate of chronic absenteeism ($R^2 = 0.40$), and most building-level associations identified in unadjusted analysis were confounded by neighborhood-level disadvantage. However, a targeted subset of building features retained independent significance after SES adjustment, and these features share a common characteristic: they reflect specific materials, practices, and exposures rather than aggregate condition ratings. Practically, the findings are consistent with four actionable directions, each requiring longitudinal or experimental confirmation before implementation:

(1) prioritizing renovation and modernization of existing facilities over new construction, given that building age showed no association with absenteeism while recent renovation did; (2) transitioning pesticide management from indoor to outdoor application protocols, given the strong contrasting associations; (3) replacing mold-susceptible ceiling materials (cellulose products) during routine renovation cycles; and (4) instituting systematic radon testing as part of standard facility management.

A second cross-cutting finding is the disconnect between inspector-assessed facility metrics and health-relevant building conditions. No aggregate rating or ordinal condition score showed a robust independent association with absenteeism, while specific component-level variables did. This pattern emerged consistently across five building categories through a four-case interpretive structure that organized the results into features that remained significant after SES adjustment (robust; e.g. recent renovation, indoor pesticide use, cellulose ceiling materials), features whose unadjusted significance disappeared after adjustment (confounded; e.g. building size, copper piping), features that became significant only after SES adjustment (suppressed; e.g. overall building rating, window condition), and features that showed no association in either analysis (null; e.g. building age, most inspector-rated condition scores). This framework helps distinguish building-attendance associations that are more likely to be independent from those that may reflect socioeconomic context or limitations of conventional facility metrics. More broadly, the study contributes a rare SES-controlled, multi-system comparative analysis of school building features and chronic absenteeism using standardized architect/engineer survey data, and shows that, in this dataset, many unadjusted building-attendance associations were attenuated after accounting for socioeconomic confounding.

AI disclosure

During the preparation of this work, the author(s) used OpenAI to improve the language. After using this tool/service, the author(s) reviewed and edited the content as needed and took full responsibility for the publication’s content.

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