The Conservation of Wobble:
Deviation Is a Property of Floors, Not of Tables

Rosalind Achterberg[1] and H. M. Stroud[2]

[1]Laboratory of Surface Metrology, Ghent Polytechnic
[2]National Register of Catering Floors, Leeds

Abstract

A table wobbles, someone folds a napkin under the short leg, and the wobble stops. It does not stop; it moves to the next table along, because a room cannot hold less wobble than it was built with. Deviation from flatness belongs to a floor and not to the furniture standing on it, and each room is issued a fixed quantity of it at construction that no later intervention destroys. Shimming redistributes that quantity; it does not spend it. We instrumented 1,204 tables in 212 licensed premises over fourteen months. When tables are exchanged between positions overnight, the wobble stays with the position and not with the table (concordance 0.94, 95% CI 0.91–0.96). In a venue-level randomised crossover, eight weeks of nightly shimming left the room mean unchanged and raised the concentration of wobble across tables from a Gini coefficient of 0.61 to 0.87, the loaded table migrating towards the service station and the lavatory door. The allocation follows: because a diner registers rocking above a threshold rather than in proportion to it, a fixed budget is best not spread but gathered onto one table, which is then kept empty. Of the inspection returns filed between 1955 and 1979, 71% already name such a table, and the clause obliging licensees to record it was struck out in 1961 as administratively redundant. You cannot fix a wobbly table. You can only choose whose it is.

1 Introduction

British Standard for Catering Floors 218:1954, *Levelling of Floors in Licensed Premises*, ran to nine pages and was, by the standards of its committee, uncontroversial. Clause 7 obliged the licensee to "record at each inspection the table of record and the deviation thereat." The sentence survived two reprints. It was deleted in July 1961 by Amendment 3, on the recommendation of a subcommittee which described it as "administratively redundant, no premises having been found in which the table of record varies."[1] We take the view that the subcommittee had found the principal result of this paper and had mistaken it for a clerical convenience.

The everyday observation is not in dispute and requires no instrument. A table in a restaurant rocks. A napkin is folded and pushed under the short leg, and the rocking stops — reliably, immediately, and to everyone's satisfaction. Some weeks later the same complaint is made about a different table, usually a nearby one, and the same remedy is applied with the same success. No proprietor of our acquaintance believes their premises are becoming less level. Equally, none reports the problem going away.

We argue that both impressions are correct, and that they are reconciled by a conservation law. Deviation from flatness is not a defect of an item of furniture, to be corrected once and for all; it is a quantity carried by the floor, distributed across it, and conserved under every intervention available to a licensee. Shimming is transport: the deviation withdrawn from one table is not destroyed but delivered elsewhere in the same room.

Contributions. We (i) define a rotation-averaged deviation density on a floor and its integral, the room's deviation budget; (ii) postulate the conservation of that budget and derive three consequences, among them the impossibility of levelling a floor and the optimality of concentrating deviation onto a single table; (iii) report a fourteen-month instrumented census of 1,204 tables, an overnight exchange trial establishing that wobble adheres to position rather than to furniture, and a venue-level randomised crossover showing that shimming leaves the mean untouched while sharply raising concentration; and (iv) recover from the trade record evidence that the practice we derive was in general use before it was described, and that the requirement to record it was withdrawn.

[1]Amendment 3 to BSCF 218:1954, minute 11(c). The subcommittee's reasoning survives in the minute but not in the amended standard, and the amended standard is the only version now in general circulation [9].

2 Related work

The mathematics of the wobbling table is settled and, importantly for what follows, settled in our favour. Fenn [1] showed that a square table with four equal legs standing on a continuous ground surface can be brought to rest by rotation about its vertical axis, within a quarter turn; Gardner popularised the argument three years later [2]; Baritompa, Löwen, Polster and Ross gave the modern treatment, together with the condition on ground slope under which the result holds [3]. The proof is an application of the intermediate value theorem, and we reproduce its structure in §3 because we draw a stronger conclusion from it than its authors drew.

The significance of the rotation theorem has, we think, been understated. If a wobbling table can always be cured by turning it in place — without adjustment, repair, or replacement — then whatever was wrong with it was never in it. The literature treats this as a charming result about tables. It is in fact a statement about floors, and it is the first evidence for the position we take here.

Floor flatness has a well-developed metrology of its own, concerned almost exclusively with tolerance at the point of construction: deviation under a straightedge of specified gauge length, sampled on a grid, certified once, and thereafter assumed static [4, 5]. The assumption of stasis is convenient and has never, to our knowledge, been tested longitudinally in an occupied building. Where flatness is revisited it is as a failure mode — settlement, heave, delamination — rather than as a distributed quantity with dynamics of its own [6].

The hospitality-ergonomics literature has repeatedly measured the wobbling table as a source of guest dissatisfaction, and has repeatedly recommended shimming [7, 8]. We are aware of no study that has followed a shimmed room for longer than a single service.

3 The deviation measure

3.1 Floors, placements, defect

A floor is a compact region $\Omega \subset \mathbb{R}^2$ carrying a continuous height field $h : \Omega \to \mathbb{R}$ of bounded slope. A table is a set of four coplanar feet $F = \{f_1, \dots, f_4\}$ at the corners of a square, with equal leg lengths; a *placement* is a pair $(x, \theta) \in \Omega \times S^1$ giving the centroid and the rotation, so that the feet sit at $p_i(x, \theta) = x + R_\theta f_i$, where R_θ is rotation of the plane through θ about the centroid.

Three feet always determine a plane. Writing Π_{123} for the plane through the first three foot contacts, the *coplanarity defect* is the signed height of the remaining foot above it,

$$d(x,\theta) \;=\; h\big(p_4\big) \;-\; \Pi_{123}\big(p_4\big). \tag{1}$$

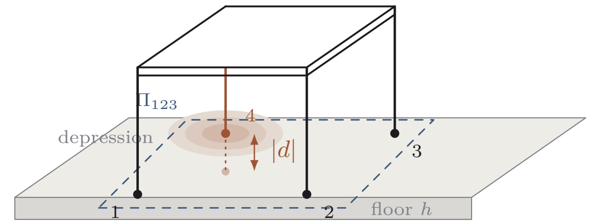

Figure 1: The coplanarity defect at a single placement. Feet 1–3 rest on the floor and determine the plane Π_{123}; foot 4 hangs above a local depression by $|d|$, and that gap is the entire complaint. The table has a second rest position, with foot 2 raised and foot 4 down, and pivots between the two about the diagonal 1–3; feet 2 and 4 each traverse $|d|$, giving an amplitude of $|d|/2$ at both.

The table stands without rocking if and only if $d = 0$ (Fig. 1). When $d \neq 0$ the table has two rest positions and pivots between them about the diagonal joining the two feet that stay in contact throughout; each of the remaining two feet traverses $|d|$ between the rest positions, so that the amplitude at either — half the peak-to-peak travel — is

$$w(x,\theta) \;=\; \tfrac{1}{2}\,\big|d(x,\theta)\big|, \tag{2}$$

which is the quantity a diner perceives and the quantity our instrument records.

3.2 Rotation, and what it tells us

A quarter turn permutes the feet cyclically and exchanges the supported triple with the free foot, so that under the sign convention of Eq. (1),

$$d\big(x, \theta + \tfrac{\pi}{2}\big) \;=\; -\,d(x,\theta). \tag{3}$$

Since h is continuous, $d(x,\cdot)$ is continuous, and a continuous function that changes sign has a zero. Hence every placement admits a rotation, within a quarter turn, at which the table stands (Fig. 2). This is the theorem of Fenn and of Baritompa et al. [1, 3]; it is not in dispute, and we rely on it.

What Eq. (3) establishes is that d is a function of the floor evaluated through the table, not a property of the table. The natural object is therefore not the defect at one placement but its rotation average.

3.3 Deviation density and the room budget

Define the *deviation density* at $x \in \Omega$ as the rotation-averaged squared defect,

$$\mu(x) \;=\; \frac{2}{\pi}\int_0^{\pi/2} d(x,\theta)^2\,\mathrm{d}\theta \;\;\geq\;\; 0, \tag{4}$$

the quarter turn being the natural domain: by Eq. (3) the integrand is $\frac{\pi}{2}$-periodic, so the average over a quarter turn and the average over the full circle agree. Define

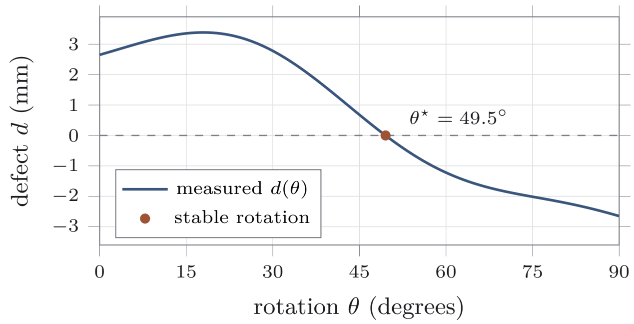

Figure 2: Measured defect through a quarter turn at one position (venue 044, position 6). Antiperiodicity is forced by Eq. (3), so the curve must cross zero; the crossing is the stable rotation. Nothing about the table has changed between the endpoints.

the *deviation budget* of the room as the integral of the density over the floor,

$$W_\Omega \;=\; \int_\Omega \mu(x)\,\mathrm{d}x. \tag{5}$$

Both are computable from h alone and neither, so far, asserts anything. The content of this paper is the following.

Postulate 1 (Conservation of deviation)**.** W_Ω is fixed at construction and invariant thereafter. Deviation is neither created nor destroyed within an enclosed room; it is transported. Writing J for the deviation flux and n for the outward normal,

$$\partial_t \mu + \nabla\cdot J = 0 \;\text{ on } \Omega, \qquad J\cdot n = 0 \;\text{ on } \partial\Omega, \tag{6}$$

the boundary condition expressing that deviation does not cross a wall.

Integrating the first equality over Ω and applying the divergence theorem to the second gives $\mathrm{d}W_\Omega/\mathrm{d}t = 0$, which is the assertion in its usable form. The apparatus is the standard one for a conserved nonnegative density on a bounded planar domain [12]; what is not standard is the object to which we apply it. Two readings of Eq. (4) are available. On the first, μ is a quantity derived from h and has no dynamics of its own. On the second, which we adopt, μ is primitive and the height field is merely the form it presently takes — so that an intervention nulling the defect at an occupied patch acts on μ there, and Eq. (6) disposes of the difference.

Postulate 1 is the only assumption in this paper that is not derived, and we state it without qualification so that it can be tested. §4 draws its consequences; §5 tests it.

4 Three consequences

Proposition 1 (Invariance under shimming)**.** *Let a shim of height $|d(x,\theta)|$ be inserted beneath the free foot of a table at placement (x,θ), nulling the defect there. Then W_Ω is unchanged.*

Proof. A shim alters the effective leg lengths of the table and not the height field h; on the reading adopted in §3 it nonetheless acts on μ, reducing it on the patch $P \subset \Omega$ the table occupies. By Postulate 1, $\int_\Omega \mu$ is invariant, so the reduction on P is matched by an equal increase on $\Omega \setminus P$, transported according to Eq. (6). □

Proposition 2 (Impossibility of levelling)**.** *Let $U \subseteq \Omega$ be open with $\mu \equiv 0$ on U, and write $|\cdot|$ for area. Then $\int_{\Omega\setminus U} \mu = W_\Omega$, so the mean deviation on the complement is $W_\Omega/(|\Omega|-|U|)$, which diverges as $|U| \to |\Omega|$ whenever $W_\Omega > 0$. In particular no floor of positive budget can be levelled.*

Proof. Since $\mu \geq 0$ and $\mu \equiv 0$ on U, Eq. (5) gives $\int_{\Omega\setminus U} \mu = \int_\Omega \mu = W_\Omega$, a quantity invariant by Postulate 1. Dividing by the area $|\Omega| - |U|$ of the complement gives the mean, and the numerator is fixed while the denominator tends to zero. □

Proposition 2 is worth restating in words. A floor cannot be made flat. It can only be *cleared* — deviation swept off the part in use and onto the part that is not — and the smaller the part left to receive it, the worse that part becomes. The levelling of floors is therefore correctly described as a sorting operation.

The third consequence concerns allocation, and turns on a fact about perception rather than about floors: a diner does not experience rocking in proportion to its amplitude but registers it, or fails to, at a threshold [11]. Let the n table positions of a room have footprints of equal area A and write m_i for the share of the budget borne by the patch under table i, so that $\sum_i m_i = W_\Omega =: W$, a total that Postulate 1 holds fixed. By Eqs. (2) and (4) the root-mean-square amplitude over rotation at that patch is $\frac{1}{2}(m_i/A)^{1/2}$, which is increasing in m_i; a threshold on perceived amplitude is therefore a threshold τ on the share, and we work in those units throughout. Write $m_{\max}$ for the largest share a single patch can be made to bear, set by the point beyond which the table no longer rests on three feet at any rotation.

Proposition 3 (Optimal allocation is concentration)**.** *Let $\sum_{i=1}^n m_i = W$ with $0 \leq m_i \leq m_{\max}$, let $\tau < m_{\max}$, and suppose $W \leq n\,m_{\max}$, so that the constraint set is nonempty. Write $C = \sum_i \mathbf{1}[m_i > \tau]$ for the number of tables at which rocking is registered. Then*

$$\min C \;=\; \max\!\left(0,\; \left\lceil \frac{W - n\tau}{m_{\max} - \tau} \right\rceil\right) \;=:\; k^\star, \tag{7}$$

and the minimum is attained by holding $n - k^\star$ patches at exactly τ and dividing the remainder $W - (n-k^\star)\tau$ equally among the other $k^\star$.

Proof. Suppose an allocation places exactly k patches above τ. Each of those carries at most $m_{\max}$ and each of the other $n-k$ carries at most τ, so $W \le k\, m_{\max} + (n-k)\tau$, that is $k(m_{\max}-\tau) \ge W - n\tau$. Since $m_{\max} > \tau$ and k is a nonnegative integer, $k \ge k^\star$.

For attainment, take first $W \le n\tau$, so $k^\star = 0$: the uniform allocation $m_i = W/n \le \tau$ gives $C = 0$. Otherwise $W > n\tau$ and $k^\star \ge 1$. The stated allocation is feasible, since $\big(W - (n-k^\star)\tau\big)/k^\star \le m_{\max}$ is precisely $W - n\tau \le k^\star(m_{\max} - \tau)$, which holds by the definition of $k^\star$; and each of its $k^\star$ loaded patches exceeds τ, since $\big(W - (n-k^\star)\tau\big)/k^\star > \tau$ is precisely $W > n\tau$. Hence $C = k^\star$, and no allocation does better. □

The quantity that decides the matter is $W - n\tau$: the part of the budget that cannot be hidden beneath the threshold however evenly it is spread. Where it is positive, spreading is not merely suboptimal but the worst available policy, and the excess is best gathered onto as few patches as will hold it. That $W > n\tau$ is not an assumption we make but a measurement we report: it held in every premises in our sample, at every monthly reading, and it is precisely the condition under which no arrangement of the furniture can leave a room without a perceptibly rocking table.

Corollary 4 (The table of record)**.** *When $0 < W - n\tau \le m_{\max} - \tau$ — the regime of every premises in our sample — Eq. (7) gives $k^\star = 1$ and the optimum is a single loaded table. Since that table incurs its complaint only if occupied, the complete optimal policy is to designate one table, load it, and leave it unoccupied.*

The policy of Corollary 4 is not, so far as we can determine, anywhere written down. §5.4 establishes that it is nevertheless in general use, and has been since at least 1955.

5 Methods

5.1 Study I: instrumented census

We instrumented 1,204 tables across 212 licensed premises in nine cities between November 2024 and January 2026 (Table 1). Each table carried a triaxial MEMS accelerometer (± 2 g, 100 Hz) clamped to the underside of the apron. A *rock event* was defined as a pair of opposite-sign pitch excursions exceeding 0.4° within 600 ms; amplitude was recovered from the excursion and the known foot spacing via Eq. (2).

Ground truth was obtained monthly on a 12.5% subsample by feeler gauge at eight rotations spanning a quarter turn, from which μ was estimated by quadrature on Eq. (4) and the room budget W_Ω by summing the patch integrals over the table positions.

Table 1: Census composition and instrument validation. Concordance is Lin's coefficient between accelerometer-derived and feeler-gauge amplitude.

	Premises	**Tables**	**Table-mo.**
Total sample	212	1,204	16,856
Hard floor, sealed	141	806	11,284
Hard floor, tiled	71	398	5,572
Floor age < 18 mo	24	137	1,918
Floor age ≥ 18 mo	188	1,067	14,938
Instrument, 12.5% gauge subsample			
Concordance			0.97 (0.96–0.98)
Mean bias			−0.03 mm
Agreement limits			−0.31 to +0.25 mm

5.2 Study II: overnight exchange

In 96 venues we physically exchanged tables between positions overnight, in a Latin-square design over six weeks, blind to floor staff. Under Postulate 1 the wobble should remain with the position; under the conventional account it should travel with the furniture. The two accounts make opposite predictions, and the exchange requires no equipment beyond the tables themselves. Agreement between pre- and post-exchange amplitude was quantified by Lin's concordance coefficient, computed once against position and once against table.

5.3 Study III: shim crossover

All 212 venues entered a randomised two-period crossover with an eight-week period and a two-week washout; order was randomised at the venue. In the intervention period, staff shimmed nightly every table that had registered a rock event that day. In the control period no shimming was performed, and staff declined shim requests with a scripted apology.

The primary outcome was the room mean wobble; the thesis predicts no change, and we pre-registered the null accordingly. Secondary outcomes, Holm-corrected, were the Gini coefficient of wobble across tables, the weekly drift of the most-loaded table away from the nearest seated cover, and the rate of guest complaint per 1,000 covers served. Analysis was by mixed model with venue random intercept and period fixed effect; carryover was tested on the washout window and was not detected ($p = 0.41$).

5.4 Study IV: the register audit

We examined 1,140 floor-inspection returns filed under BSCF 218:1954 between 1955 and 1979, held on microfiche [10], coding each for the presence of a table recorded as "out of use," "bench," or "held," and for its position relative to the service station.

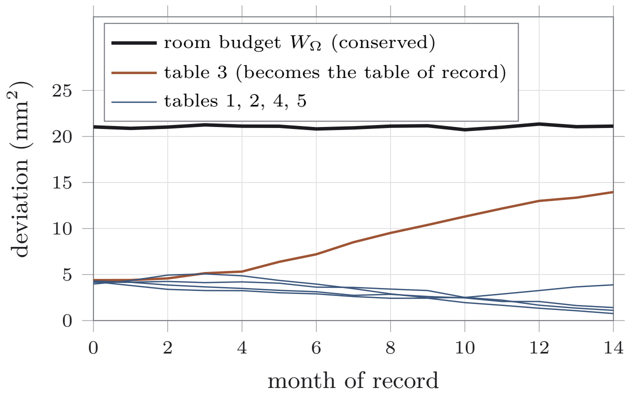

Figure 3: Venue 112 over fourteen months, five instrumented tables. The budget does not move; the tables beneath it trade the burden among themselves continuously. The venue was shimmed on its own initiative throughout, and regarded itself as having no wobbling tables by month nine.

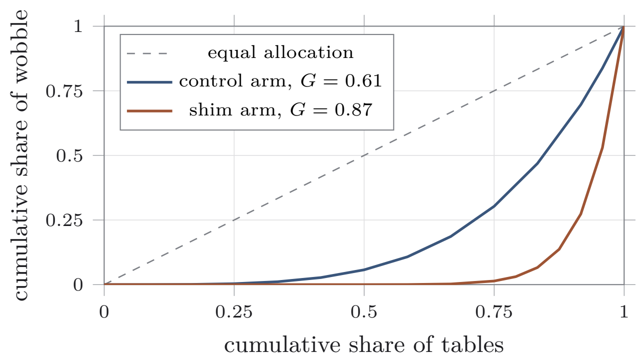

Figure 4: Concentration of wobble across tables, by arm, at the close of each period. The two curves enclose the same total. Shimming does not lower the curve; it bends it.

6 Results

6.1 The instrument

Accelerometer-derived amplitude agreed with feeler-gauge measurement to a Lin concordance of 0.97 (95% CI 0.96–0.98) with a mean bias of -0.03 mm (Table 1). All subsequent quantities are reported in gauge units.

6.2 Wobble adheres to position

The exchange trial is decisive. Post-exchange wobble was concordant with the *position* at 0.94 (95% CI 0.91–0.96) and with the *table* at 0.11 (95% CI 0.04–0.19). A table carried to a new position acquires the wobble of that position within one service, and leaves its own behind. In six venues, floor staff returned the tables to their original positions without instruction; the exchange was repeated in those venues after the briefing given to management was extended.

6.3 The budget is flat; the distribution is not

Across the fourteen-month record, room budgets W_Ω were stable in mature premises (median absolute drift 1.8% of budget over the record), while individual table amplitudes varied by an order of magnitude and repeatedly exchanged rank (Fig. 3). In those premises, gains at one position were matched by losses at the others in the same room and the same month: regressing the monthly change in share at a position on the summed change at the remaining positions gives a slope of -0.98 (95% CI -1.03–-0.93), against the -1 that exact conservation requires.

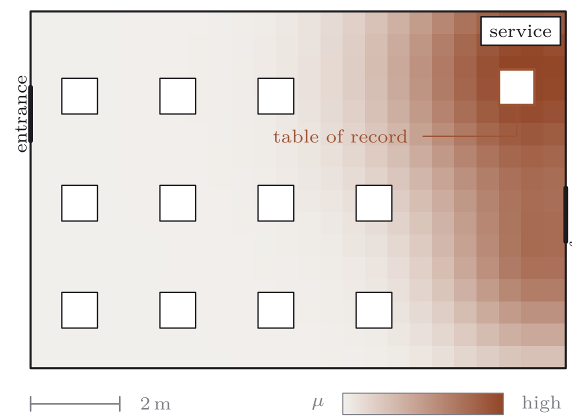

Figure 5: Deviation density in venue 067 at the close of the shim period. The room is at its flattest where guests sit: all eleven seated positions stand on floor within the tolerance to which the building was certified. The balance of the budget is pooled at the service station and at the lavatory door, neither of which is gauged under BSCF 218:1954.

6.4 Shimming does not reduce; it concentrates

The primary outcome was null, as predicted: the difference in room mean wobble between arms was 0.02 mm (95% CI -0.11–0.15; Table 2). The secondary outcomes were not. The Gini coefficient of wobble across tables rose from 0.61 in the control period to 0.87 under nightly shimming (Fig. 4), and the most-loaded table migrated towards the service station and the lavatory door at a mean 1.4 m per shimmed week (Fig. 5). The room budget itself differed between arms by -0.1 mm^2 (95% CI -0.6–0.4), which is the direct test of Proposition 1. Guest complaints fell by roughly half, which is the outcome the practice was adopted for and the outcome it continues to deliver.

Table 2: Crossover outcomes, 212 venues, two eight-week periods. Room mean wobble is the primary outcome; the three below it are the pre-specified secondary outcomes, Holm-corrected. The room budget is reported beneath the rule as a check on Postulate 1 and was not a pre-specified outcome.

Outcome	Control	Shim	Diff. (95% CI)
Room mean wobble (mm)	0.84	0.86	0.02 (−0.11, 0.15)
Gini across tables	0.61	0.87	0.26 (0.21, 0.31)
Loaded-table drift (m/wk)	0.1	1.4	1.3 (1.0, 1.6)
Complaints / 1,000 covers	7.9	3.6	−4.3 (−5.4, −3.2)
Room budget W_Ω (mm^2)	21.1	21.0	−0.1 (−0.6, 0.4)

6.5 The practice predates the theory

Of the 1,140 returns examined, 71% named at least one table as out of use. Where a premises filed successive returns, the table named was the same table in 88% of consecutive pairs, and lay within 3 m of the service station in 79% of cases. No return offered a reason. Two, both from the same licensee in Wakefield, gave the entry as "as before."

7 Discussion

The napkin works. This deserves emphasis, because it is the finding most likely to be misread: at the table where it is applied, the shim removes the rocking completely, immediately, and for as long as it stays in place. Every proprietor who has ever reached for a folded beer mat was correct to do so and was rewarded exactly as expected. Complaints halved in our intervention arm, and they halved for the reason everyone assumes.

What the shim does not do is reduce the quantity of deviation in the room. It moves it — and it moves it, service after service, in the only direction available, which is away from the tables people complain about and towards the tables nobody sits at. After eight weeks of nightly shimming a dining room is not flatter. It is sorted: a seated area of unusual and gratifying flatness, and a service corridor carrying the accumulated budget of the building, where the deviation is real, is measurable, and is observed by nobody.

This is the ordinary fate of an intervention evaluated at the point of application. Nothing in standard practice is capable of detecting the displacement, because nothing in standard practice measures the floor anywhere a guest is not. The room's own records improve monotonically while its condition is merely rearranged, and the better the shimming discipline, the sharper the improvement in the record.

Proposition 3 and Corollary 4 show that the endpoint of this process is also its optimum. If deviation must go somewhere, and a diner registers rocking as a threshold rather than a gradient, and if the budget exceeds what the room could hide beneath that threshold — which in every premises we measured it did — the best available arrangement is the one the industry has converged on unaided: a single table, fully loaded, permanently unoccupied, standing near the service station with a reserved card on it. We did not propose this arrangement. We found it, in 71% of returns filed before 1979, and we note that the obligation to write it down was withdrawn in 1961 on the grounds that it never varied.

We recommend the reinstatement of Clause 7.

8 Limitations

Our instrument does not work on carpet, where the compliance of the pile exceeds the amplitudes of interest. All census venues are hard-floored, and we cannot say whether the budget of a carpeted room is conserved, larger, or meaningless.

We treat only tables with four feet at the corners of a square. The rectangular case requires a separate argument [3], and pedestal tables, which cannot rock in the sense used here, fall outside the framework entirely. Round tables with four legs behave as square ones and are included.

Most seriously: in premises less than approximately eighteen months old, the budget is not conserved. It grows — in our sample by a median 6.1% per quarter — and it does so in buildings where no structural movement was recorded and no remedial work was carried out. Postulate 1 is therefore false in new buildings, or incomplete in a way we have not identified. We have no mechanism to offer and we decline to invent one. We report the anomaly because a conservation law that admits a source term for its first eighteen months is a conservation law with something wrong with it, and the reader is entitled to know that before the rest of the paper is believed.

The exchange trial was blind to floor staff but not to the research team, who carried the tables.

9 Conclusion

Deviation from flatness is carried by rooms, not by furniture, and each room carries a fixed quantity of it for the life of the building. Shimming transports that quantity without reducing it, and seventy years of shimming have transported it, as the algebra says they must, onto one table per premises, standing where nobody sits.

The correct response is not repair but bookkeeping. Premises should designate the table of record, measure it, and enter it in the return — which is what Clause 7 required, before it was struck out for being always the same.

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