Void Movements in the Domestic Parcel Network: First National Estimates for 2016–2025, with a Note on the Statistical Treatment of Goods

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Abstract

The box was too big for what was inside it. It was the right size for what was being sent, which was the empty space. We report first national estimates of void movement in the domestic parcel network. Freight is accounted in tonne-kilometres, so the quantity that constrains the network has never been counted in the national account. Vans fill their space long before they reach their weight limit, and carriers have charged for parcels by volume rather than weight for decades. Measuring 41.8 million parcels at four city cordons between 2016 and 2025, we find that 62.4% of the volume the network moves is empty space (95% CI 61.8–63.0). The void is not a residue of packing. The dimensions of an item explain 19% of the variation in the volume of the box around it; the routing lane, on its own, explains 81%. Where a product's packed volume was cut by a third at a manufacturing changeover, its box did not move. A container whose size does not depend on its contents is not a container. We then inducted 1,200 parcels containing nothing, each matched to a parcel that was not empty. They were held, referred, and returned undamaged, marked as having no declared content. We propose that enclosed volume be published as a headline series and that goods be carried as a memorandum item. The box is not the packaging. The thing inside it is.

Keywords: void fraction; dimensional weight; freight accounts; cordon survey; parcel logistics

1 Introduction

The domestic freight account is denominated in tonne-kilometres. A movement enters the statistics as a mass carried over a distance, and the resulting series have been published on that basis, with minor revisions of scope, since 1954. The account is internally consistent and is used with confidence by operators, regulators and the transport ministries.

It does not measure the quantity that constrains the network.

Goods vehicles in parcel service reach their cubic capacity well before they reach their permitted mass; the trade calls this cubing out. It is the ordinary operating condition of a domestic parcel van (Aldiss and Pemberton, 2019). Carriers have accordingly priced by volume rather than mass, in the great majority of consignments, since the introduction of dimensional weight in scheduled air freight and its subsequent adoption on the ground (Brügger, 2011). A network whose binding constraint is volume, whose vehicles are dispatched on volume, and whose customers are billed on volume is nonetheless recorded in a national account that contains no volumetric term.

The consequence is not a rounding error. Where the enclosed volume of a consignment has been measured at all, it has been measured as a defect — an efficiency loss to be designed out — rather than as a flow to be counted (Deveraux, 2020). Twenty years of right-sizing programmes have proceeded on

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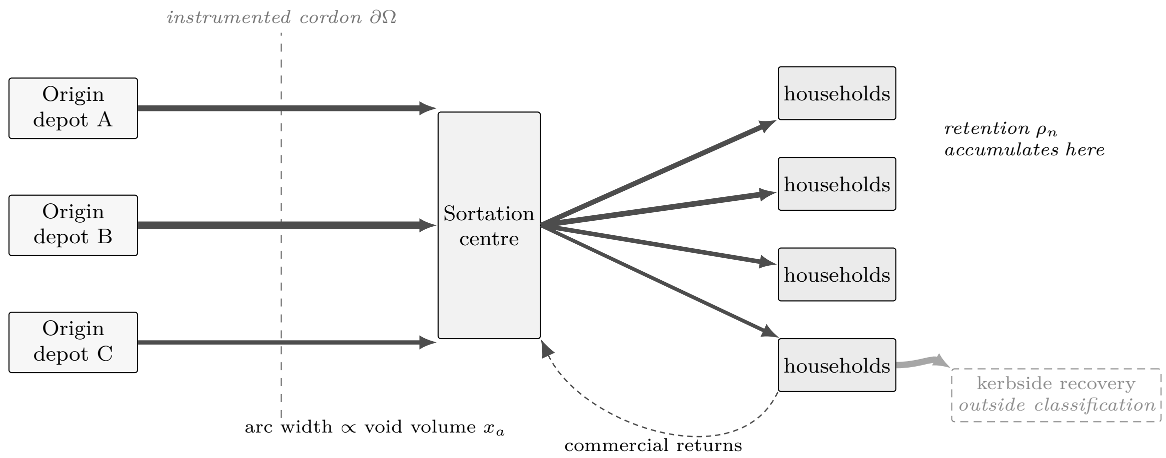

Figure 1: Schematic of the accounted network and the cordon. Arc widths are proportional to conveyed void volume x_a. Void enters the household nodes and is not observed to leave them by any arc within the classification; the terminal release at kerbside recovery is not a scheduled movement and does not enter equation (5).

that basis. This working paper takes the opposite view. The quantity is large, it is moving, and it is not counted.

Section 2 sets out prior measurement. Section 3 gives definitions and the accounting framework. Section 4 describes the Cordon Volume Survey (CVS) and the nil-content induction trial. Section 5 reports estimates. Section 6 sets out quality, coverage and the revisions policy. Sections 7 and 8 discuss limitations and propose a statistical treatment.

2 Background and prior measurement

Dimensional weight. Every major carrier assesses a consignment at the greater of its actual mass and a volumetric equivalent obtained by dividing its enclosing cuboid by a fixed divisor δ:

$$w_{\mathrm{dim}} = \frac{L\,W\,H}{\delta}, \qquad w_{\mathrm{chg}} = \max(w_{\mathrm{act}},\, w_{\mathrm{dim}})\,, \tag{1}$$

with $\delta = 5{,}000\,\mathrm{cm}^3\,\mathrm{kg}^{-1}$ across the domestic services in scope. For the sampled population, $w_{\mathrm{dim}} > w_{\mathrm{act}}$ in 88.1% of consignments: for nearly nine parcels in ten, the mass of the goods is not a term in the price.[1]

Load factor and cube-out. Utilisation audits of urban distribution fleets consistently report vehicles departing at 78–86% of cubic capacity and 34–41% of permitted payload (Aldiss and Pemberton, 2019; Kessel, 2022). The literature treats the gap as underloading. It is more simply read as a full vehicle.

Right-sizing. On-demand carton manufacture and cartonisation heuristics have been deployed at scale since the late 2000s (Cartwright and Osei, 2017). Reported gains are real at the level of the individual consignment and do not appear in network-level cubic utilisation, which has been flat to two significant figures over the same period (Deveraux, 2020). We draw no inference from this. The phenomenon has resisted a sustained and well-funded effort to remove it.

What the accounts contain. The standing guidance on domestic freight statistics defines the unit of observation as a laden movement and the measure as mass carried (Office for Movement Statistics, 2024). Enclosed volume appears nowhere in the classification. The Statistical Commission on Freight Accounts considered the question at its fifteenth report and deferred it, on the ground that enclosed volume is a property of packaging rather than of freight (Statistical Commission on Freight Accounts, 2023). Section 5 bears on that ground.

[1] Given δ, the condition $w_{\mathrm{dim}} > w_{\mathrm{act}}$ is equivalent to a gross consignment density below $200\,\mathrm{kg\,m^{-3}}$; at $\varphi = 0.624$ this is satisfied wherever declared contents are less dense than roughly $450\,\mathrm{kg\,m^{-3}}$.

3 Definitions and accounting framework

Void fraction. For a consignment i with enclosing box volume V_i^{box} and total displaced volume of declared contents V_i^{item}, the void fraction is

$$\varphi_i \;=\; 1 - \frac{V_i^{\text{item}}}{V_i^{\text{box}}} \;\in\; [0,1), \tag{2}$$

and the volume-weighted aggregate over a set S is $\varphi_S = \sum_{i\in S}\varphi_i V_i^{\text{box}} \big/ \sum_{i\in S} V_i^{\text{box}}$. Dunnage and protective fill are treated as contents where declared and as void where not; the sensitivity of φ to this choice is reported in Section 6.

The accounted network. Let $G=(N,A)$ be a directed graph whose nodes are depots, sortation centres, delivery rounds and household termini, and whose arcs are scheduled movements. Write x_a for the void volume conveyed on arc a over the reference period. At an interior node conservation holds exactly, since a parcel is neither opened nor consolidated in transit:

$$\sum_{a\in\delta^-(n)} x_a \;-\; \sum_{a\in\delta^+(n)} x_a \;=\; 0, \qquad n\in N_{\text{int}}. \tag{3}$$

At a household terminus there is no outward arc in scope, and the divergence is retained:

$$\rho_n \;=\; \sum_{a\in\delta^-(n)} x_a, \qquad n\in N_{\text{hh}}. \tag{4}$$

Summing (3) and (4) over a region Ω bounded by a cordon $\partial\Omega$ gives the identity we estimate,

$$\underbrace{\sum_{a\in\partial\Omega} \sigma_a\, x_a}_{\text{cordon flux}} \;=\; \underbrace{\sum_{n\in\Omega\cap N_{\text{hh}}} \rho_n}_{\text{retention}} \;+\; \varepsilon_\Omega, \tag{5}$$

with $\sigma_a = \pm 1$ the cordon orientation and ε_Ω a closure error carrying survey, grossing and scope effects. Kerbside recovery, by which retained void is ultimately released, is not a scheduled movement of a consignment and is therefore outside the classification (Ntuli, 2021); it does not appear in (5) and cannot at present be brought into it.

The entitlement condition. A consignment carries a declaration D_i, being the description, class and value entered against it at induction. Sortation exception handling admits a movement to the network if and only if $D_i \neq \varnothing$. The rule is not a policy about goods; it is the observability condition. An automated sorter cannot distinguish a consignment that declares nothing from a consignment whose declaration failed to read, and resolves both to the same exception (Hallgrímsdóttir and Renko, 2018). We write

$$\Delta_\ell \;=\; \Pr\big[\text{completion} \mid V^{\text{box}}, \ell, D\neq\varnothing\big] \;-\; \Pr\big[\text{completion} \mid V^{\text{box}}, \ell, D=\varnothing\big] \tag{6}$$

for lane ℓ, and estimate Δ_ℓ in Section 5.4.

4 Data and method

4.1 The Cordon Volume Survey

Dimensioning gantries were installed on the goods-vehicle approaches to four conurbations and operated from January 2016 to December 2025 on the operating days shown in Table 1. Every parcel crossing a cordon on a sampled vehicle was cubed in motion; accuracy against static reference cubing is $\pm 1.4\,\%$ on the linear dimensions at cordon speeds (Marchetti and Sowande, 2016). Cubing at induction is already universal for billing under (1), so the survey adds observation of the cordon crossing rather than of the parcel.

Contents were dimensioned on a consented sub-sample of 214,911 consignments at the delivery point, following the test method of BS 7899:2021 (British Standards Institution, 2021). Grossing to national totals uses vehicle counts from the continuous traffic census, with post-stratification on carrier, service class and month. Coverage and grossing factors are given in Table 1.

Table 1: Cordon Volume Survey: coverage and grossing, 2016–2025.

Cordon	Operating days	Parcels dimensioned	Contents sub-sample	Grossing factor
Northern conurbation	3,629	12,904,881	66,218	7.41
Estuarial conurbation	3,652	15,117,402	78,330	6.88
Western conurbation	3,588	8,442,190	43,106	9.02
Border conurbation	3,511	5,341,859	27,257	11.34
Total	—	41,806,332	214,911	—

Grossing factors are period means; monthly factors are published in the accompanying dataset.

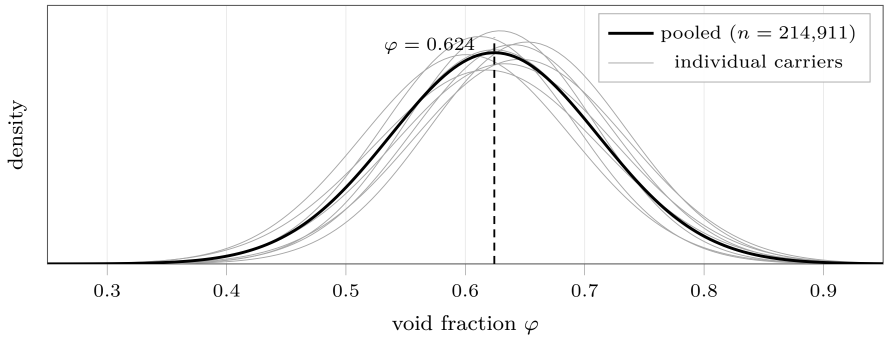

Figure 2: Distribution of the void fraction φ, pooled and by carrier, 2016–2025. The carrier densities are not separated (ICC = 0.04). On the mean domestic service profile a vehicle reaches cubic capacity before permitted payload at every void fraction in the plotted range.

4.2 The redesign discontinuity

Eleven consumer products underwent a dated reduction in packed volume of at least 30% at a manufacturing changeover during the reference period, with no change of carrier, service class or routing lane. Consignments of those products were tracked for twenty-six weeks either side of the changeover date, giving a sharp discontinuity in V^{item} against which V^{box} may be read.

4.3 The nil-content induction trial

2,400 parcels were inducted at eighteen sites under a two-arm design. Parcels were matched in pairs on external dimensions, gross mass (ballasted to tolerance with a distributed inert mass), label class, insurance band and lane, and randomised within pair to contain either a declared low-value item or nothing. Randomisation was concealed from induction staff. The primary endpoint was completion of delivery within the published service window; secondary endpoints were recorded exception codes and physical condition on return.

5 Results

5.1 The void fraction

Over the reference period the volume-weighted void fraction of the domestic parcel network is

$$\varphi \;=\; 0.624 \quad (95\%\ \text{CI}\ 0.618\text{–}0.630).$$

Just under two thirds of the volume moved by the network is enclosed void. The distribution of φ across nine carriers is given in Figure 2; it is unimodal, tight, and does not separate by carrier (ICC = 0.04), which is the first indication that φ is a property of the network rather than of any firm's packing practice.

5.2 Box volume is not explained by contents

We regress box volume on the volume of the item it encloses, with fixed effects for the routing lane ℓ (origin depot × sortation centre × service class):

$$V_i^{\text{box}} \;=\; \alpha \;+\; \beta\, V_i^{\text{item}} \;+\; \lambda_{\ell(i)} \;+\; u_i. \tag{7}$$

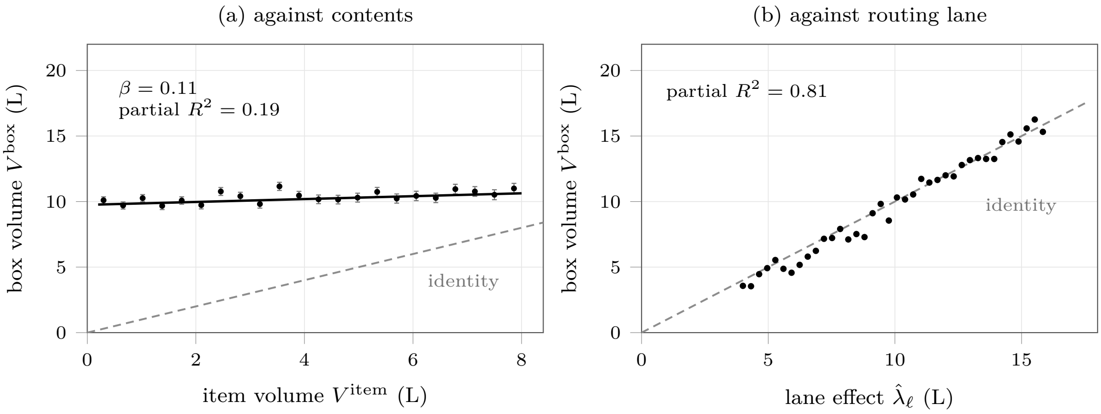

Figure 3: Box volume against contents (a) and against routing lane (b), binned means with 95% intervals. Bins are equally spaced in V^{item} and are not equally populated; the volume-weighted mean item volume is 3.89 L against a mean box volume of 10.35 L. The dashed line is the identity in both panels. A twenty-six-fold range of item volume moves the box by rather less than a litre; the lane accounts for the rest.

Table 2: Variance decomposition of box volume, equation (7).

Term	Partial R^2	Coefficient	95% CI
Item volume V^{item} (L L^{-1})	0.19	$\beta = 0.11$	0.09–0.13
Routing lane λ_ℓ	0.81	—	—
Declared mass	0.00	−0.01	−0.03–0.01
Fragility flag	0.01	0.04	0.01–0.07
Model	0.86	—	—

Partial R^2 are computed against the full model and do not sum to the model figure. Standard errors clustered by lane.

Partial R^2 is 0.19 for V^{item} and 0.81 for the lane effects (Table 2). The coefficient on item volume is $\beta = 0.11$ litres per litre (95% CI 0.09–0.13), an elasticity at the sample means of 0.043: a doubling of the item enlarges its box by four per cent.

Figure 3 shows the relation directly. Against item volume the cloud is flat. Against lane mean it is close to the identity line. The box is sized to the journey and not to the object.

5.3 The redesign discontinuity

Across the eleven redesigned products, item volume fell by a mean of 37.2% at the changeover date. The mean change in box volume over the same discontinuity is +0.4% (95% CI −1.9 to +2.7), with no pre-trend before the change and no drift after it (Figure 4). Where a manufacturer removed a third of an object, the network continued to move the volume it had been moving.

5.4 The nil-content induction trial

Of the 1,200 nil-content parcels inducted under the design of Section 4.3, 38.2% completed delivery within the published service window and 41.6% completed at any time, against 98.9% of their matched controls, none of which completed after the window closed. The risk ratio for non-completion is 53.9 (95% CI 31.3–92.8); proportional hazards is strongly violated and no hazard ratio is reported. Survival curves are given in Figure 5.

The failures are administrative in every case. The recorded exception codes are NCD (no content declared, 61.2% of failures), REF (referred to exceptions desk, 27.4%) and RTS (returned to sender, 11.4%). No nil-content parcel was recorded as damaged, mis-sorted or lost. The void is not fragile. It is unpermitted.

5.5 The cordon balance

Table 3 reports the balance (5) for the reference year 2025. Net retention across the four cordons is 1.9×10^5 m^3, with a closure error of 2.7% of gross inflow. Inflow has grown at 6.8% a year over the

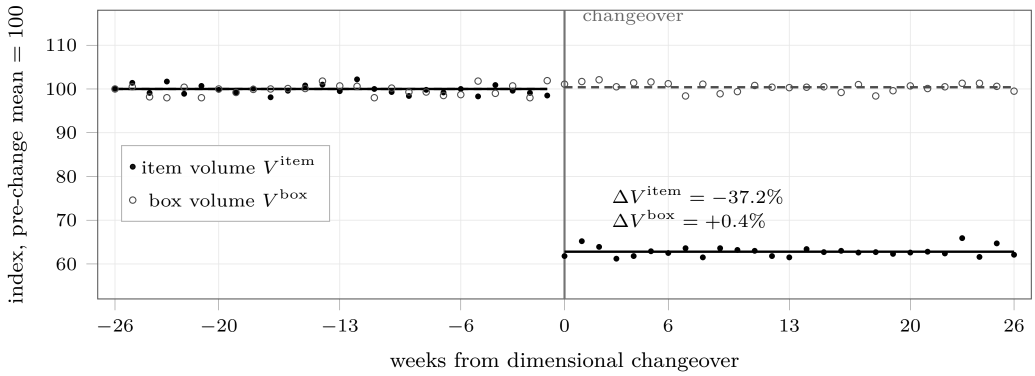

Figure 4: Item volume and box volume in event time about a dated dimensional changeover, pooled over eleven products in unchanged lanes. Item volume falls by rather more than a third. Box volume does not move.

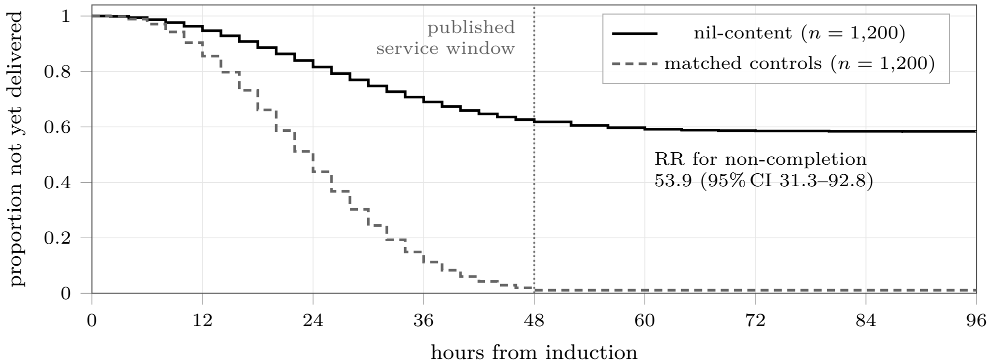

Figure 5: Kaplan–Meier estimates from induction to delivery. The nil-content arm does not fail progressively; it arrests. Parcels that had not cleared exception handling by roughly the second day did not subsequently clear it.

reference period, spanning the 2019 comparability break; the mass of goods conveyed on the same arcs has grown at 0.3% a year and is not distinguishable from flat after 2021 (Figure 6).

6 Quality and methodology

Coverage. The cordons observe an estimated 79% of domestic parcel movements by volume. Movements originating and terminating within a cordon are out of scope and are not grossed. Refrigerated and pharmaceutical services are outside the scope of the survey and are excluded from all estimates; their treatment is discussed in Section 7.

Comparability. The series is not directly comparable before 2019. Two of the four gantries were re-sited in that year and the contents sub-sample was extended to include protective fill as a separately recorded category. The effect of the change on φ is +0.008, estimated by parallel running over eleven months, and has not been carried back through the series.

Treatment of dunnage. Treating all protective fill as contents rather than as void in (2) lowers φ to 0.541; treating all fill as void raises it to 0.669. Neither bound alters the finding in Section 5.2, which concerns the relation between box volume and item volume and does not depend on where fill is assigned.

Non-response. Consent for contents dimensioning was declined at 8.2% of delivery points. Decliners differ from consenters on service class but not on V^{box}; the non-response adjustment moves φ by less than 0.003.

Closure. The residual ε_Ω in Table 3 is 2.7% of gross inflow. We attribute it to unobserved commercial returns and to the exclusion of within-cordon movements. It is reported as a residual and is not distributed.

Table 3: Cordon void balance, reference year 2025. Volumes in 10^3 m^3.

Cordon	Inflow	Outflow	Retention $\sum \rho_n$	Closure error
Northern conurbation	71.4	12.9	56.7	1.8
Estuarial conurbation	88.1	16.2	69.4	2.5
Western conurbation	46.3	8.4	36.5	1.4
Border conurbation	32.0	5.9	25.3	0.8
Total	237.8	43.4	187.9	6.5

Closure error is stated as a residual and is not distributed across the components.

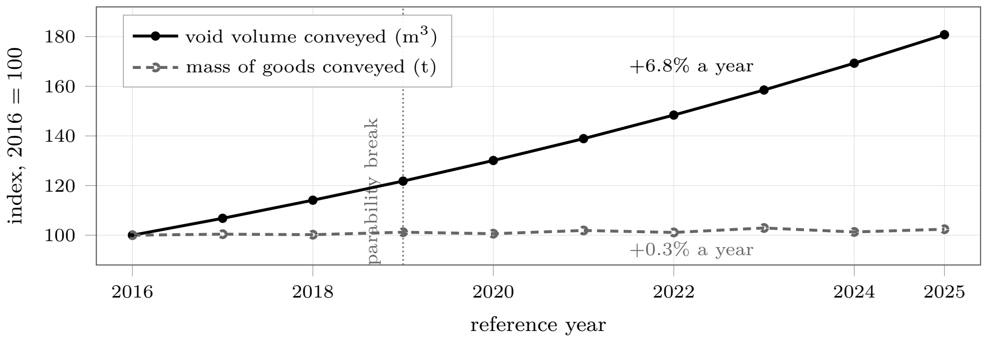

Figure 6: Void volume and goods mass conveyed on the same arcs, 2016–2025. The two series are collected from the same vehicles on the same movements. Estimates for 2024 and 2025 are provisional.

Revisions. Estimates are provisional. The 2024 and 2025 reference years will be revised at the next release when the traffic census benchmarks are reweighted; revisions of ±2% to grossed volumes should be expected. The void fraction φ is a ratio of survey quantities and is not affected by benchmark reweighting.

7 Discussion and limitations

The three results in Section 5 are of different kinds and should be read in order. The variance decomposition establishes that the box is not a function of its contents. The redesign discontinuity establishes that this is not an artefact of cross-sectional matching: the same product, in the same lane, with the same carrier, lost a third of its bulk and kept its box. The nil-content trial establishes the direction of the dependence. Void does not move because goods require protection; goods move because void requires a declaration.

That dependence is the paper's substantive claim. It is not a claim about motive. No carrier need intend it, and the evidence in Section 2 suggests that several have spent considerable sums attempting the opposite. The network conveys volume because volume is what fills its vehicles, what it prices, and what it dispatches against. The goods are the term that makes a given volume admissible to the classification.

Limitations. The framework does not describe refrigerated and pharmaceutical lanes. In those lanes $\varphi = 0.11$, box volume tracks item volume ($\beta = 0.94$), and the lane fixed effects carry no explanatory weight. Equation (7) fits them poorly and the entitlement condition adds nothing to their description. We have no account of why these lanes behave differently. They are excluded from all estimates above, and the exclusion is material.

Second, the closure error in Table 3 exceeds the 2% tolerance set for provisional series. Third, retention ρ_n is a residual quantity: no instrument observes void inside a dwelling, and the household term is obtained by difference. Kerbside recovery would in principle permit a consistency check, but it is not classified as a freight movement and is not collected on a basis that could be reconciled with (5).

8 Proposed statistical treatment

We recommend three changes to the domestic freight classification.

1. **Enclosed volume becomes a headline series.** Void movements should be published quarterly in cubic metres and cubic metre-kilometres, on the same release calendar as tonne-kilometres, and should be the primary measure of parcel network activity.

2. **Goods become a memorandum item.** The mass and description of declared contents should continue to be collected, since the entitlement condition (6) makes them necessary to the movement, and should be published below the line as a memorandum item rather than as the measure of activity. This is a change of presentation and does not affect the underlying collection.

3. **Kerbside recovery is brought into scope.** Retention ρ_n can only be validated against the terminal release of void. We recommend that kerbside material recovery be reclassified as a terminal freight movement for statistical purposes, which would close (5) directly rather than by residual.

Adoption would record the domestic parcel network as the survey finds it: the largest scheduled movement of empty volume in the country.

9 Conclusion

Just under two thirds of what the parcel network moves is nothing. The proportion does not vary by carrier, does not respond to twenty years of packaging reform, and is not predicted by what is inside the box; it is predicted by where the box is going. When a manufacturer made its product smaller, the box stayed the size it was. Boxes sent with nothing in them came back undamaged and unsent, marked as having declared no content.

The goods are not the consignment. They are the entitlement, and they should be recorded as such.

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