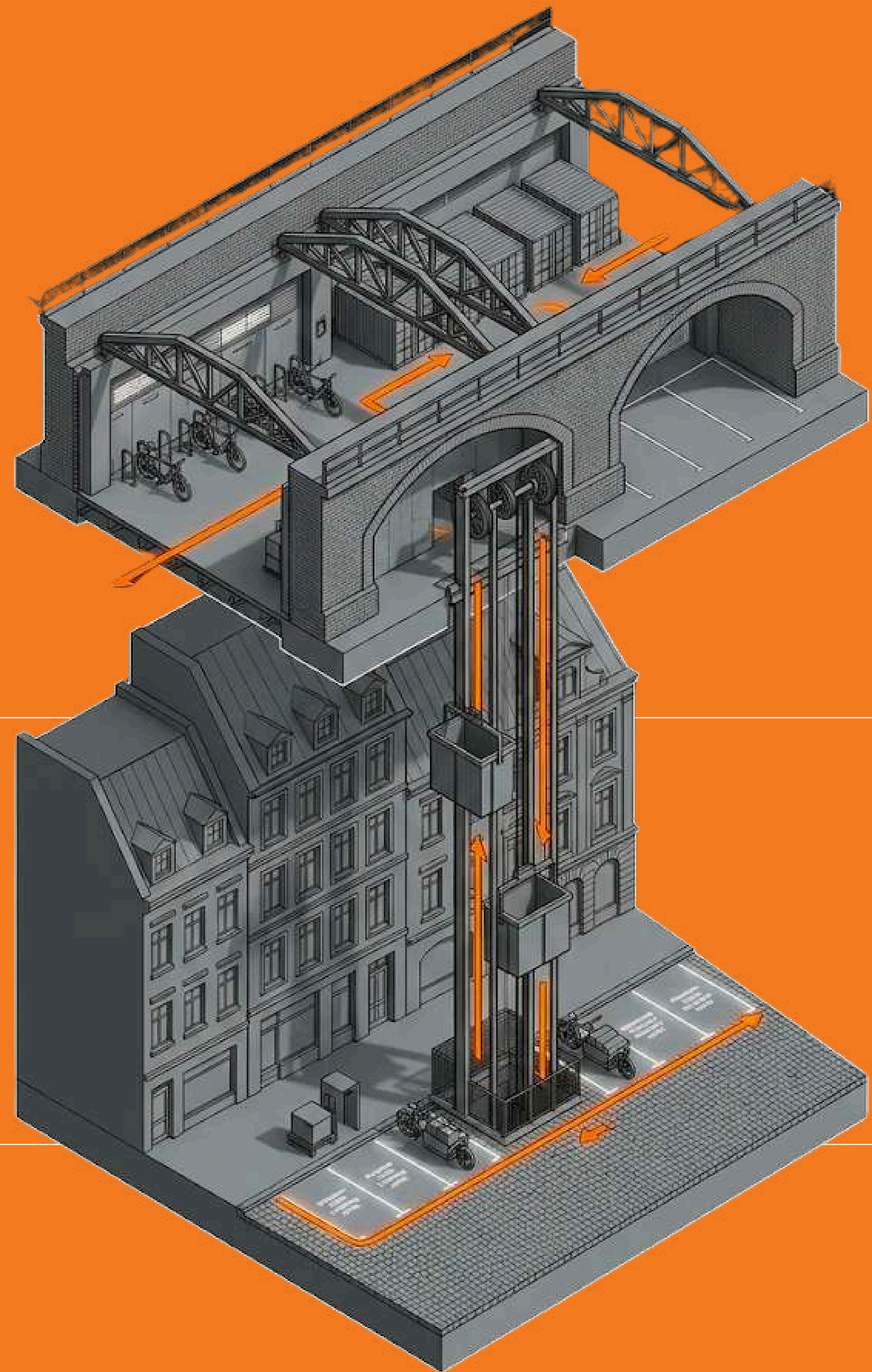


B E F O R E T H E W A L L

A Scalable Three-Layer Infrastructure
Framework for Zero-Emission Logistics
Shock



ABSTRACT

Zero-emission zone regulation is forcing a change most people misread: heavy trucks were never the ones stopping outside city-centre shops - narrow streets already excluded them decades before any emissions rule existed. What's actually changing is where freight breaks bulk. A process that used to happen invisibly, scattered across a hundred anonymous depots on cheap land, is being collapsed by regulation into one visible point at the city boundary - and nothing was designed to catch it there.

This project proposes a three-layer system to absorb that collapse, sited in Amsterdam, where the strongest zero-emission enforcement in Europe already overlaps with a working consolidation precedent. A boundary hub, sited in reused industrial space rather than new construction, performs the truck-to-van break-bulk that the regulation forces into existence, run by a neutral third-party operator so competing carriers never share sensitive data with each other. A microhub, built into reused urban space such as a disused railway arch, brings consolidation closer to demand without ever admitting a truck. A counterweighted physical connector - the same principle as a funicular, a loaded container's descent pulling an empty one back up - links the microhub to its nearest curb, where scheduled time-slot booking replaces first-come competition and a reserved-access mechanism protects small shops from the same capital gap that already threatens to exclude them from ZEZ compliance itself.

The system is not invented from first principles. Every component traces to a documented precedent: Mail Rail's 76 years of single-operator reliability, Beaugrenelle's proof that reused space beats new excavation, Gnewt Cargo and UCC Amsterdam's decade-plus operation without ongoing subsidy, and Cargo Sous Terrain's 2025 collapse as an explicit lesson in what not to attempt at scale. The financing bet - public capital for construction, carrier fees for operation, no ongoing subsidy - is checked directly against the three published conditions the literature identifies for consolidation survival, all three confirmed true for this site.

The system was stress-tested against three genuine failure modes - sustained heat stressing shared grid capacity, political softening of the ZEZ mandate, and the EU's packaging reuse regulation converting waste into a circulating asset. The analysis found the scenarios are not independent: two pull in opposite directions on the same floor space, and two compete for the same grid connection at their worst simultaneously. Impact is measured by delivery vehicle entries into the zone per 1,000 parcels, chosen specifically because it isolates the system's own contribution from the regulation's, and holds steady even if total delivery volume grows. A phased budget, beginning at €55,900 to prove the mechanism before €383,000 is committed to prove it at scale, keeps every commitment gated by evidence rather than a calendar. Proven at pilot scale in one city, the system is structurally transferable to the 28 other Dutch municipalities enforcing identical regulation by 2030, without requiring a new mechanism for each one.



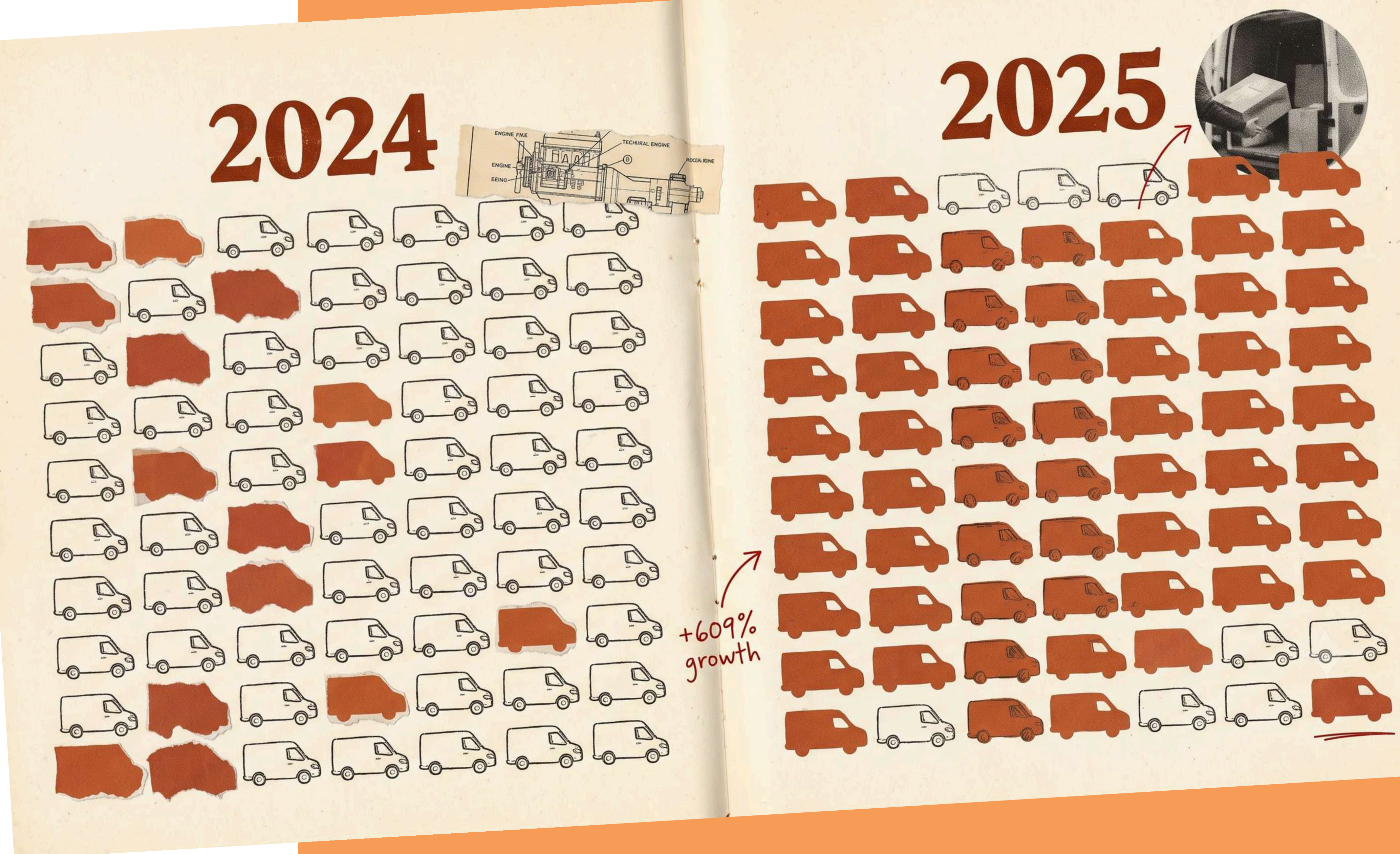
Urban last-mile / a system, not a vehicle

THE TRUCK THAT WAS NEVER COMING

You have never watched a forty-ton truck squeeze down your street to make a delivery. That's not because it was banned. It merely never planned to come that far.

Long before any city outlawed anything, the streets themselves did the work regulation now gets credit for. No room to swing a trailer around a corner. No loading dock built for anything that size. A truck that big merely had nowhere to put itself down, so it never tried. That's a fact about pavement and property lines, not policy - it was true decades before anyone wrote a zero-emission rule.

What in practice pulled up outside your building, every single time, has always been more ordinary: a van, hazards blinking, half on the curb, easy enough to overlook that most people never register it as policy-itry vehicle at all. It was the only vehicle that could physically do the job..



There is one truck you have seen, though, and probably didn't notice either: the one that pulls straight up to the loading dock behind the supermarket or the big-box store on the wider road at the edge of the center and unloads a single full load in one stop. That one's diesel too. And that one is banned now, precisely the same as the van - not because of its size, but because of what comes out of its exhaust.



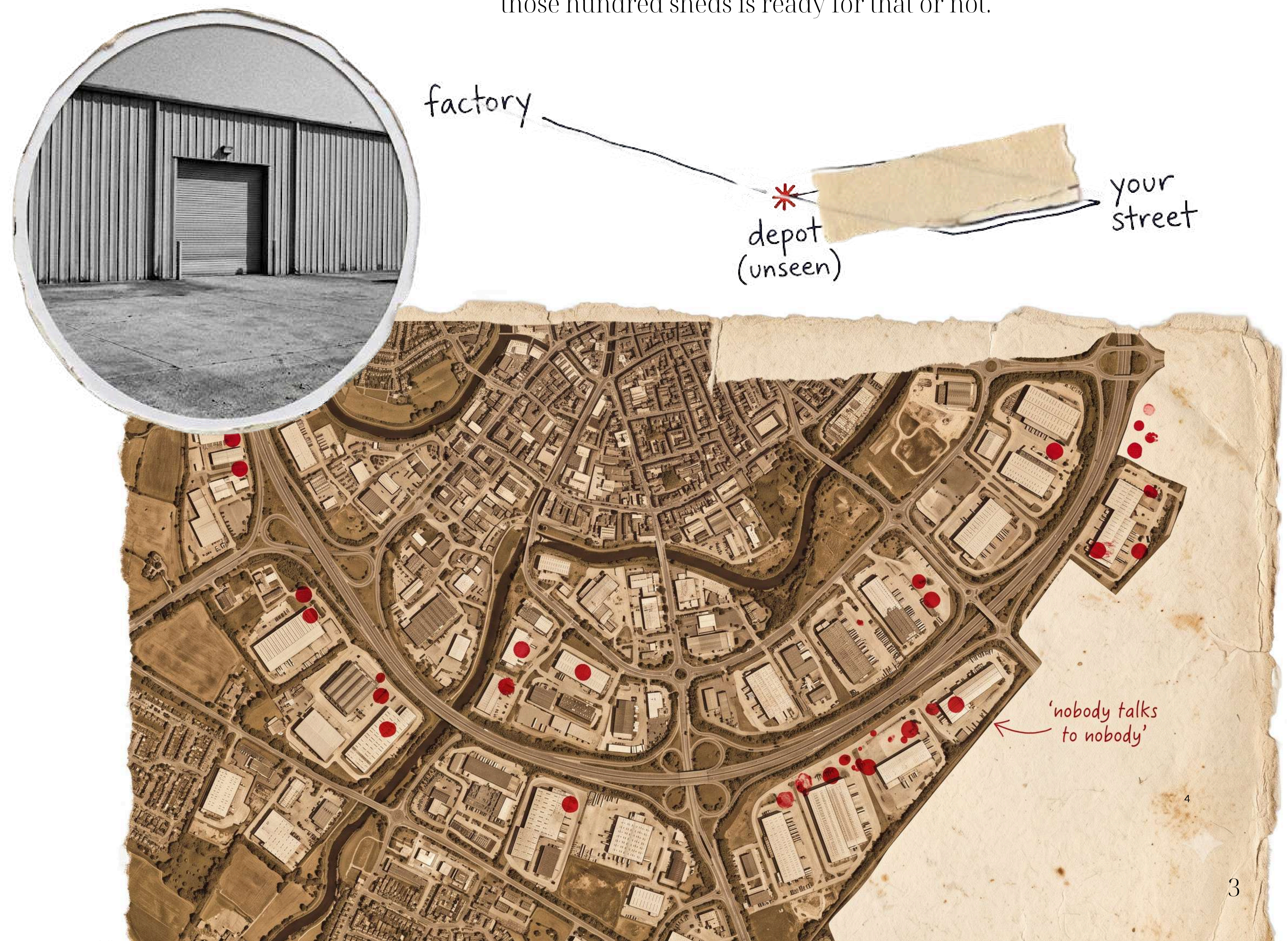
Before the wall
IT BY NOW
HAPPENED. YOU
JUST WEREN'T
STANDING THERE.

This isn't a gap in the system. It's the system working precisely as intended - just working somewhere by design out of sight, spread across dozens of interchangeable buildings instead of concentrated in one place anyone would think to look. Invisibility was never an accident here. Cheap land and low visibility are the same real-estate decision, made independently, over and over, by companies that never had a reason to talk to each other about it.

The hand-off by now exists. What changes is where it happens., by now happens daily, by now works, in its scattered and uncoordinated way. The shift is in where it's allowed to happen at all - collapsed from a hundred private, invisible sheds into one publicly visible edge, whether the system currently spread across those hundred sheds is ready for that or not.

That truck's last stop was never your street. Its actual destination is a depot you've never had a reason to notice - off a ring road, behind an industrial estate, wherever land was cheap enough to build a shed nobody was ever meant to look at twice. Long-haul freight is built on one simple economic logic: keep a load consolidated for as long as possible, because splitting it early costs money for no reason. So the split happens as late as it can, right at the edge, in whichever anonymous building happened to have room.

There, invisibly, every single day, for every parcel entering the city, the big load gets broken apart and reloaded onto something smaller. Nobody schedules this around your specific city's traffic. Nobody coordinates it with the depot two kilometers down the same ring road doing the exact same job, for a different company, at the exact same hour. Each shed runs its own version of the same process, entirely blind to every other shed doing it in parallel.



The situation - the ambition

A MOON LANDING HAS NO SMALL PRINT

"Today is the start of a journey. But this is Europe's man on the moon moment."

-Ursula von der Leyen, 2019

On 11 December 2019, twelve days into her term, Commission President Ursula von der Leyen stood in front of the European Parliament to present the Green Deal for the first time. She didn't undersell it. "Today is the start of a journey," she told them. "But this is Europe's man on the moon moment."

Two days later, presenting the same plan to the same chamber, Vice-President Frans Timmermans reached for the same reference - by design, word for word echoing Kennedy's 1962 speech at Rice University. "We choose to go for climate neutrality in 2050," he said, "not because they are easy, but because they are hard." That's the line by now sitting on the first page of this deck, before either name was attached to it. Two of the people who wrote this policy, addressing the same room within 48 hours of each other, reached for the exact same metaphor without coordinating it as a talking point. That's not an accident of speechwriting. It's precisely what the ambition in practice felt like from the inside.

A moon landing is a specific kind of promise, and it's worth taking the comparison literally rather than as decoration. It isn't a target you can invisibly miss and adjust downward later. It's binary - you get there, or the entire program was theater, watched by everyone, with nowhere to hide the failure. That's the frame Europe's own leadership chose, on purpose, to describe climate neutrality by 2050.

'Getting there' actually requires everything the rest of this project deals with - the emissions trajectory, the zones already enforced in Dutch cities, the hub, the curb, the mechanism - once the metaphor lands back on solid ground. The ambition was never the missing piece. Nobody in either speech doubted the destination. Neither speech addressed, and no speech at that podium was ever going to address, the part this project exists to answer: where the mess lands when a continent-scale target meets one real, specific street.



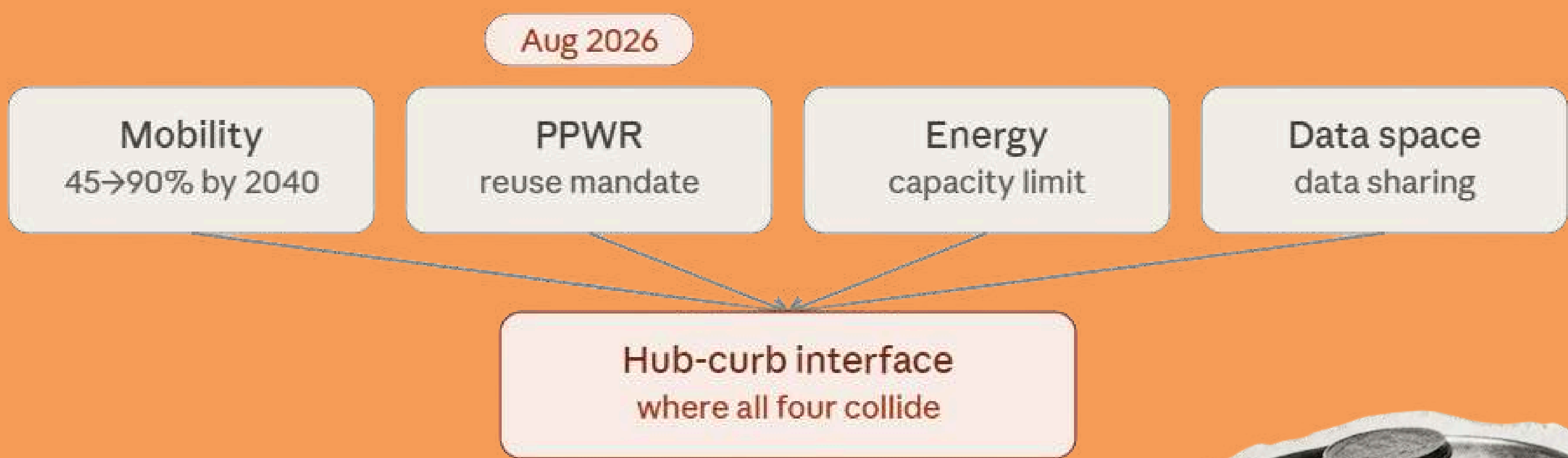
The situation- the full picture

ONE DEAL, FOUR SEPARATE LEVERS - POINTED AT THE SAME STREET

The Green Deal isn't one policy, and treating it as one is where most projects touching this topic go shallow. It's Europe's plan to reach climate neutrality by 2050, and it touches almost everything - energy, farming, buildings, industry, biodiversity, trade. Most of that never comes near a delivery van. Four pieces do, written by different Commission teams, at different times, with no shared coordination between them - and each one lands on a different part of the system this project is proposing.

Sustainable and Smart Mobility Strategy is the piece by now established: heavy-vehicle emissions cut 45%, 65%, 90% by 2030, 2035, 2040, translated at street level into zero-emission zones. This is the lever that forces the break-bulk wall into existence in the first place - everything on the last three pages traces back to this one document.

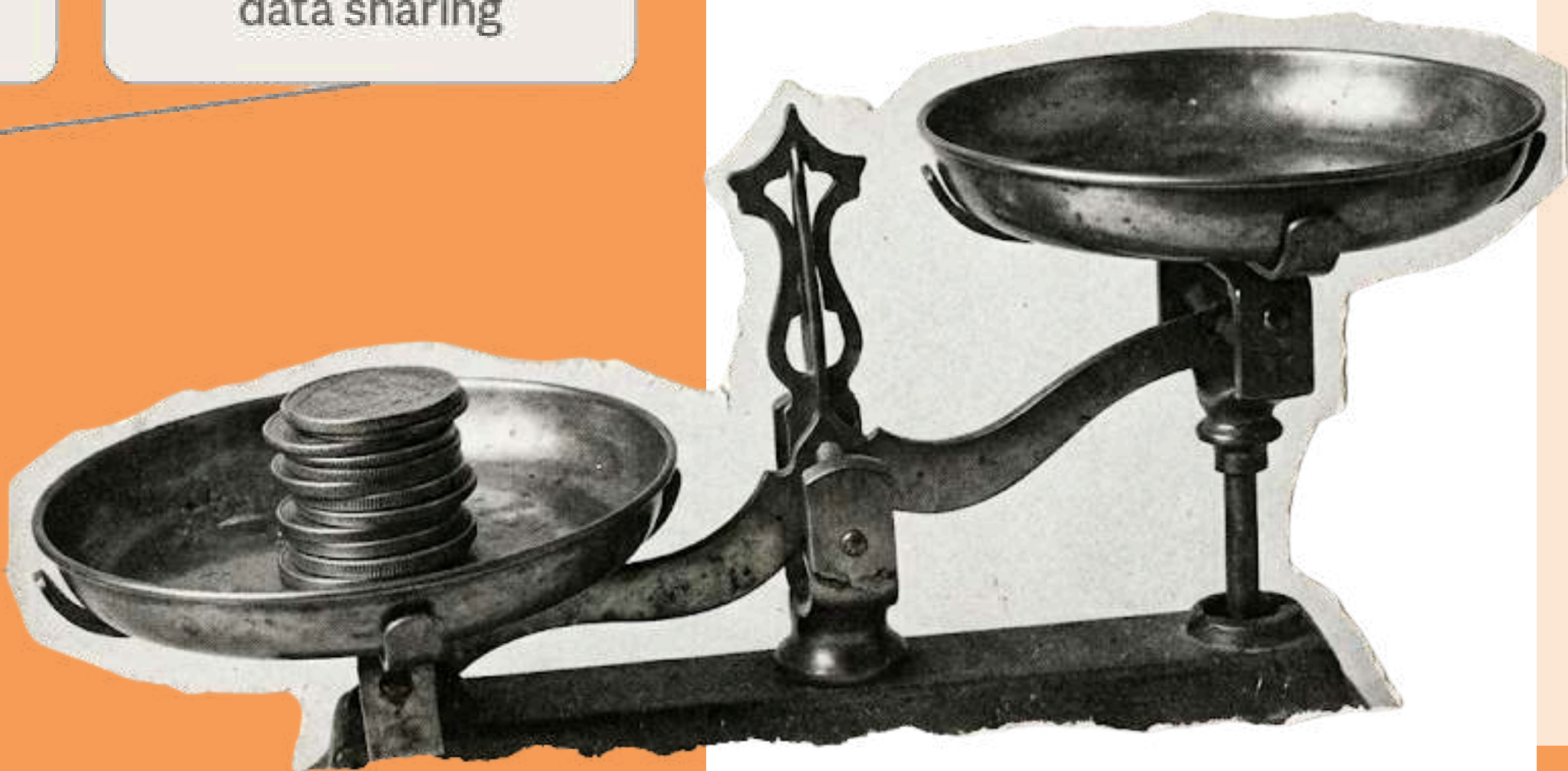
Circular Economy Action Plan, specifically the Packaging and Packaging Waste Regulation, is the quieter one. Reusable packaging becomes a legal requirement for e-commerce from August 2026 - three weeks after this project's own submission deadline. This is what turns the return trip from merely inefficient into non-compliant: a delivery vehicle leaving a hub empty isn't just wasting a trip anymore, it's failing a legal requirement that didn't exist a few years ago.



Energy System Integration Strategy is the Deal's own language for balancing new electricity demand against what the grid can physically carry. This is the document that makes charging dozens of vehicles overnight a real, load-bearing constraint on this project's design - not a footnote to mention once and move past.

Common European Mobility Data Space exists because logistics companies don't share operational data with each other by default, and someone at the policy level had to write that down as a problem worth solving. This is the EU-level version of the exact coordination gap this project's neutral-operator model by now answers at the scale of a single hub.

Four separate documents. Four separate drafting teams. Years apart, no meetings between them. And they all still converge on the same physical square meter: wherever the hub and the curb in practice meet.



The situation- if nothing changes

WHAT THE CURRENT SYSTEM PRODUCES UNDER FULL POLICY COMPLIANCE

Run everything from the last four pages forward precisely as written, add no new infrastructure, and four measurable effects follow - not as speculation, each one traceable to a specific mechanism by now established.

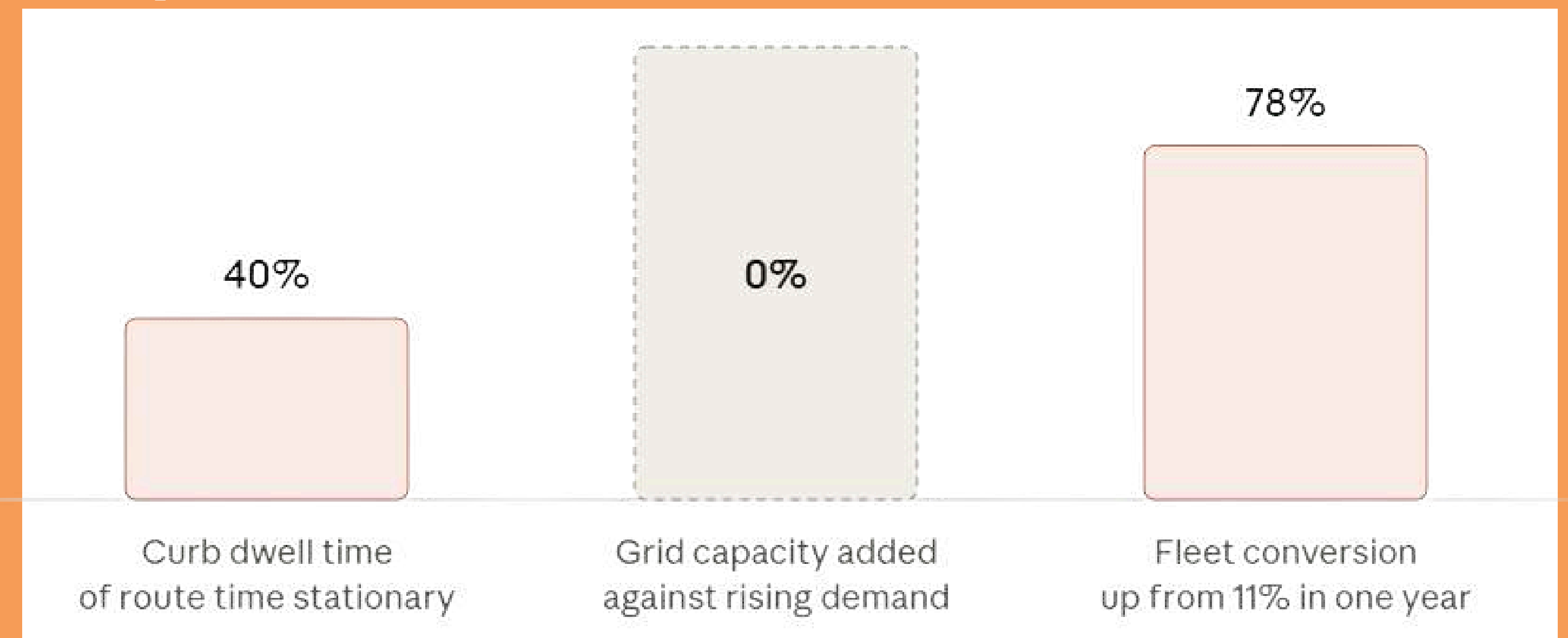
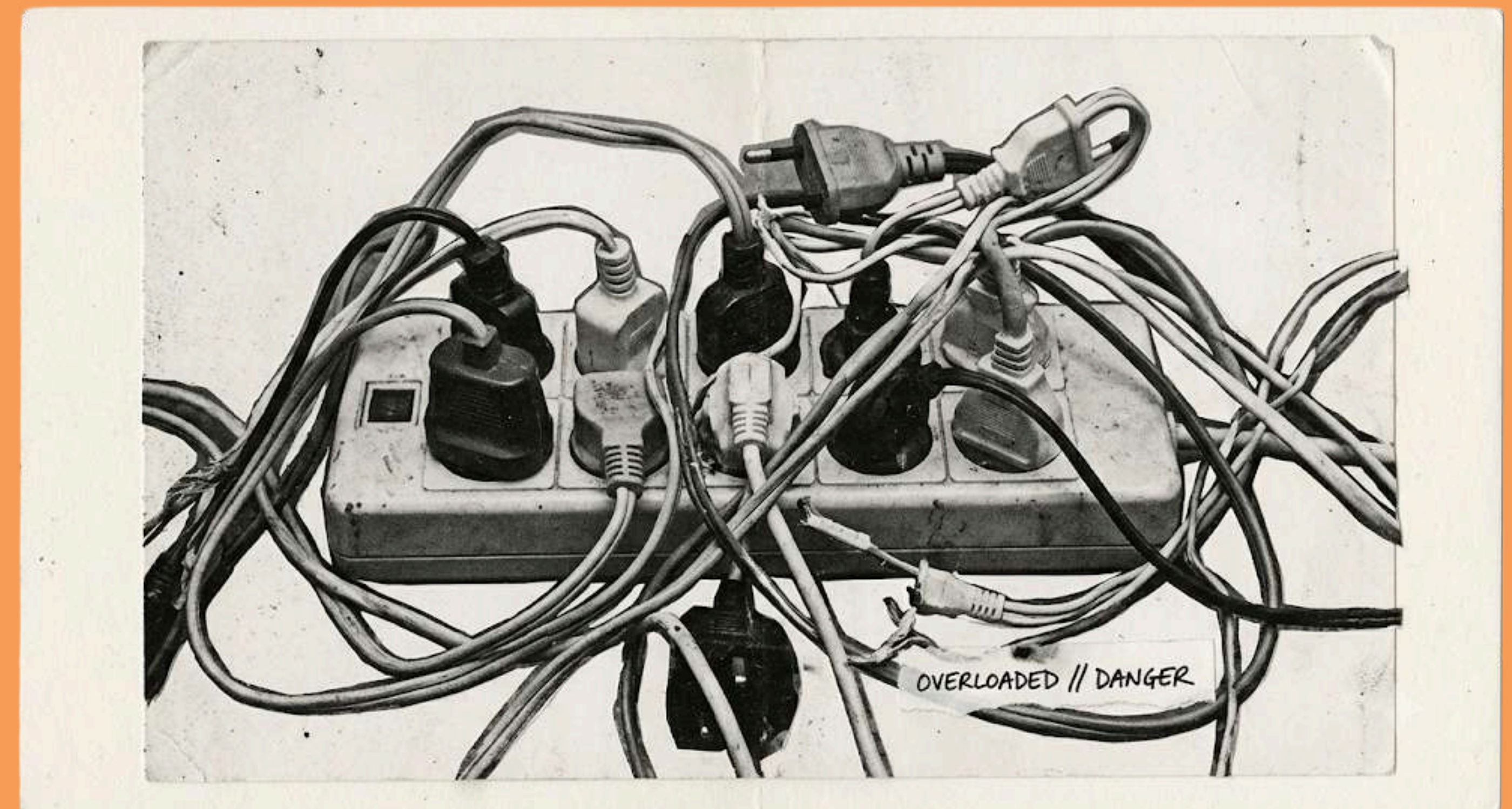
Vehicle count rises. One truckload split across several small electric vehicles instead of one large one is by now a documented pattern in early ZEZ enforcement, generally referred to as vehicle sprawl. The freight volume doesn't change. The number of individual vehicles carrying it does - more stops, more separate trips, same total cargo.

Curb time increases. Delivery vehicles by now spend up to 40% of route time stationary, frequently double-parked, in cities without dedicated loading infrastructure. That number was measured under today's vehicle count. A higher vehicle count competing for the same fixed curb length extends it, not reduces it - the math only moves in one direction from here.

Charging demand concentrates. Dutch battery-electric van registrations rose from 11% to 78% of new registrations within a single year of enforcement. That speed of fleet conversion, without a matching increase in local grid capacity, produces something specific: dozens of vehicles converging on the same charging window overnight, against a substation limit that doesn't grow just because the fleet did.

Break-bulk relocates informally. Where no dedicated consolidation space has been designed, the sorting step observed in unregulated cases by now happens in improvised locations-parking lots, highway shoulders, transition streets - rather than anywhere built for it. The hand-off doesn't disappear when there's no hub to catch it. It just goes somewhere nobody planned for.

Four separate pressures. One shared cause: policy compliance without designed absorption.

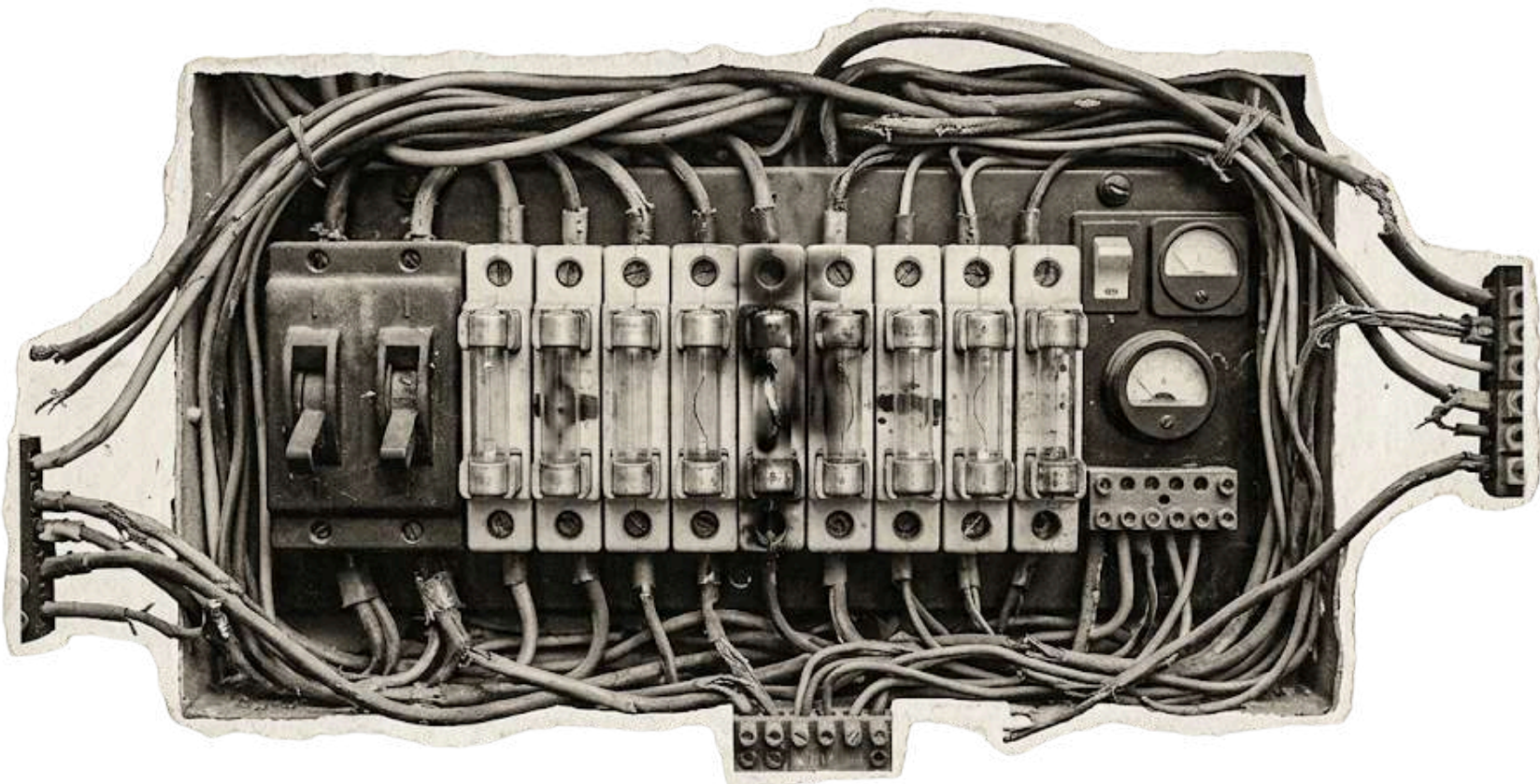
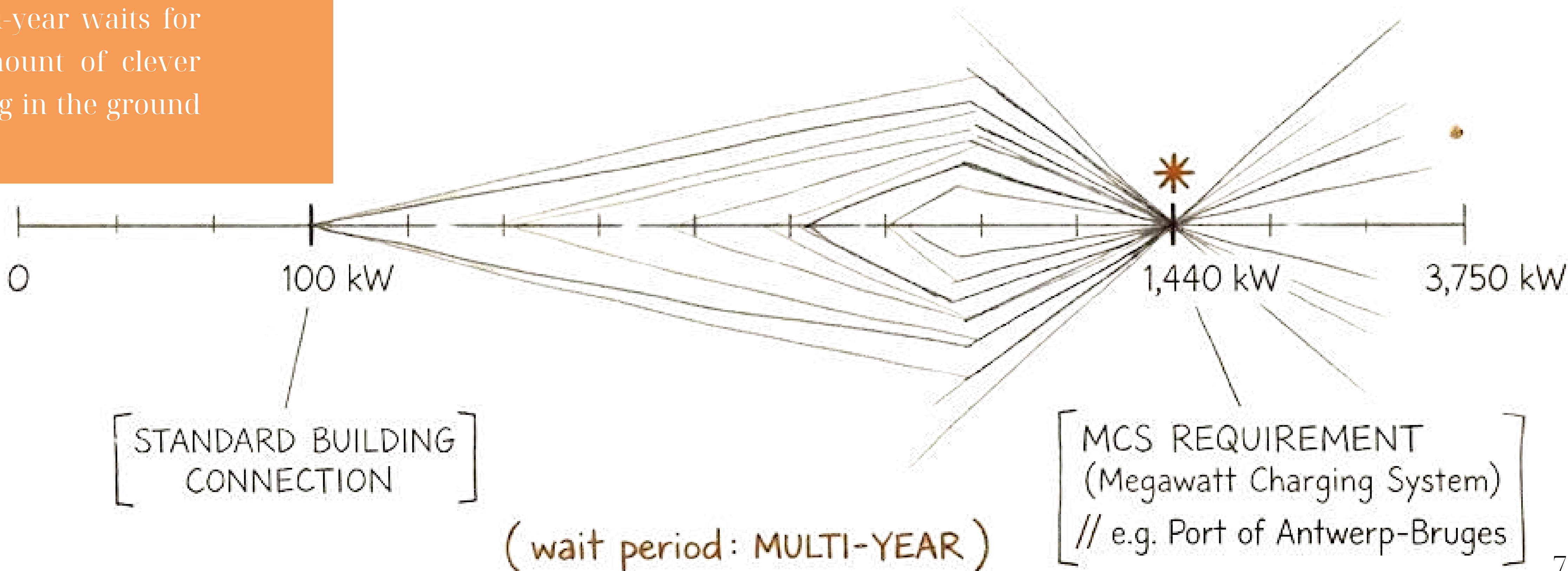


THE GRID CONSTRAINT IS TWO
SEPARATE LIMITS, NOT ONE

Everything on the last page's charging-demand bar collapses into one word - grid - as if it's a single problem with a single fix. It isn't. It splits cleanly into two constraints that behave nothing alike, and treating them as one is where a lot of well-intentioned charging infrastructure plans go wrong before they're even built.

Capacity is physical, and fixed once a site is chosen. How much power in practice exists at that location, full stop. The emerging charging standard for heavy vehicles, MCS, is rated up to 3.75 megawatts - real chargers by now running at 1.44 MW each, roughly the load of a small apartment block, through a single connection. That doesn't come from a standard building's electrical supply. It needs a dedicated high-voltage feed, and in several major European cities, local substations are by now near their limit before this demand gets added - new connections can face multi-year waits for upgrades that have to happen first. No amount of clever scheduling changes how much power is sitting in the ground at a given corner.

Allocation is a decision, made continuously. Given whatever capacity exists, who gets to use it, and when. Multiple carriers sharing one hub hit the same fight as curb access - several parties, one limited resource, the same hour. Unlike capacity, this one by now has a working answer: tiered, priced access that spreads charging across off-peak hours instead of every vehicle plugging in at once. Confuse the two and a project tries to solve a concrete-and-copper problem with a booking app, or a scheduling problem with a substation upgrade it never needed.



The mechanism - street space

THE SPACE CONSTRAINT ALSO SPLITS IN TWO



Illustrative - the same reused space, before and after adoption

Same two-part shape as electricity, and that's not a coincidence worth glossing over - it's the same underlying pattern showing up twice, which is evidence of how this kind of constraint in practice works.

Siting is physical, and fixed once a location is chosen.

Where the break-bulk activity in practice happens, decided once, before anything opens. A site either works or it doesn't - there's no operational fix for picking the wrong one. New excavation is expensive at any real scale, by now established against Cargo Sous Terrain's failure. Reused dead space isn't, and it's not theoretical: a five-year lease under a London railway viaduct, 39 parking spaces converted inside an existing City of London structure, an underground garage repurposed in Paris. None of these needed new construction.

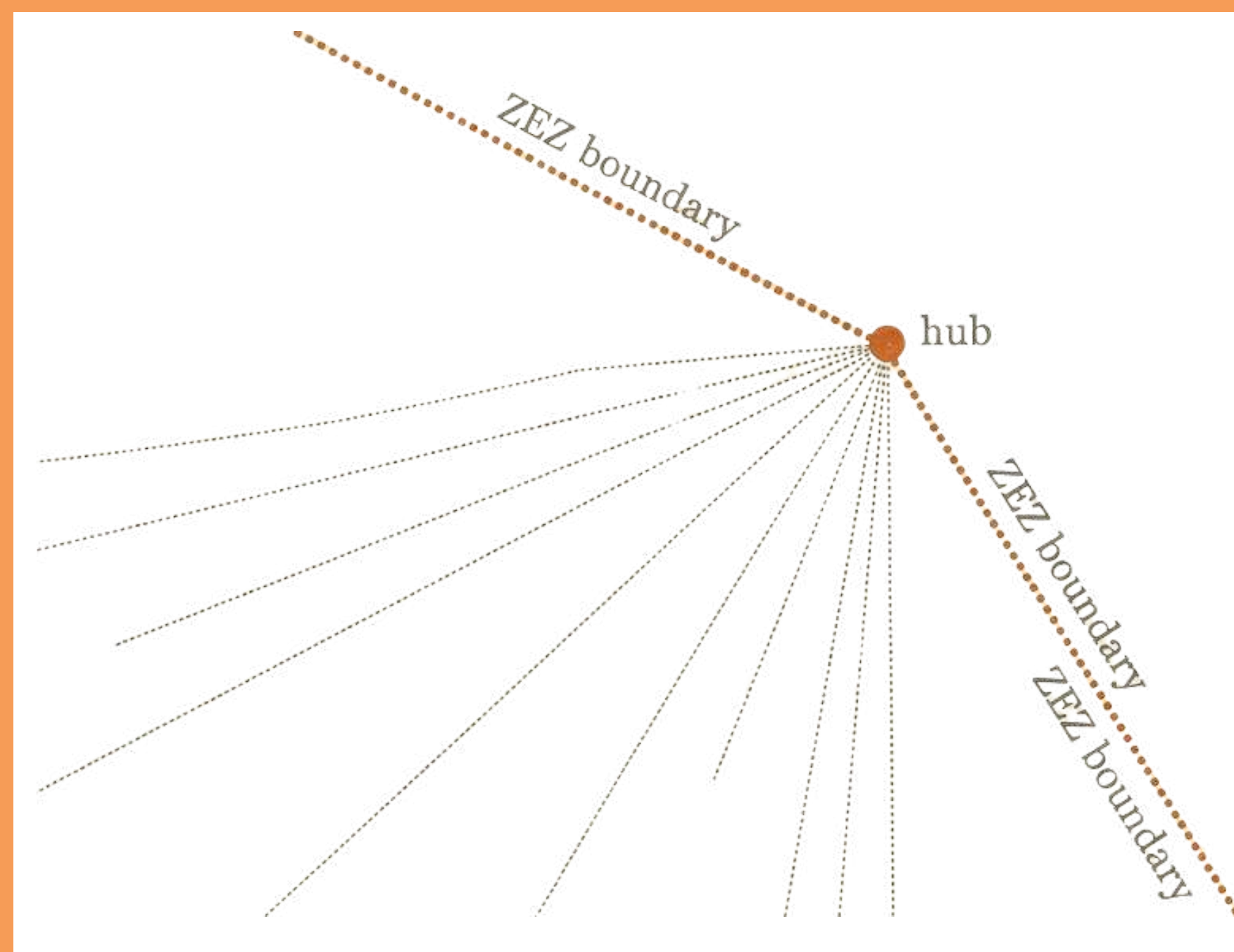
Curb allocation is a decision, made every

day. Who gets to stop at a loading bay, and when. Delivery vehicles by now spend up to 40% of route time stationary, frequently double-parked, competing for the same fixed curb length - the same number from the no-intervention scenario. Unlike siting, this has a working answer by now: scheduled time-slot booking, adapted from dock-appointment systems standard in freight logistics.

Same pattern, both constraints: one half gets decided once and holds for the project's life. The other gets decided continuously, every day the system runs.

The split - outer city

EVERYTHING BEFORE THE WALL

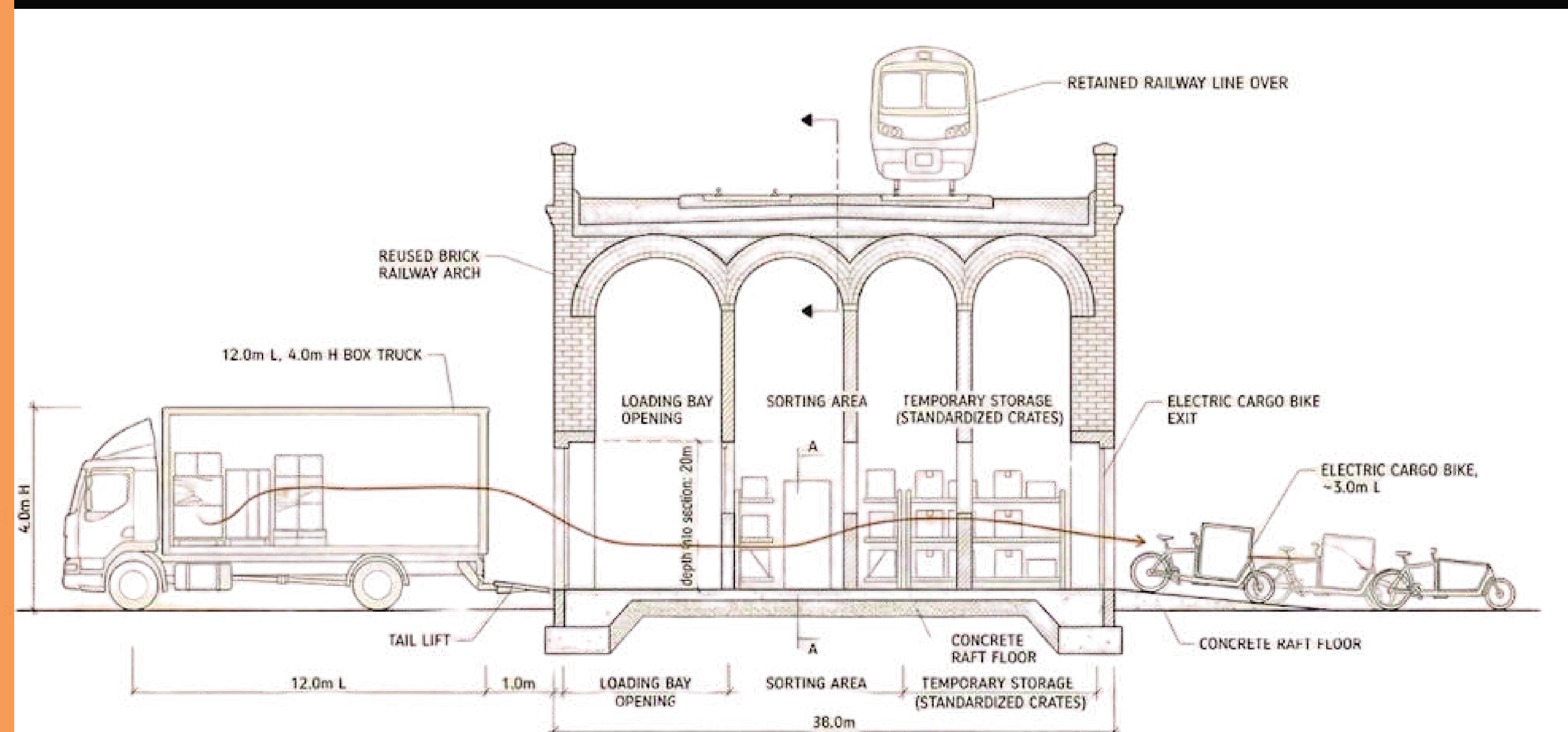


Zoom out one level from the last two pages, and a clean division falls out of everything just established: the entire system splits into two halves, and each one has been invisibly following its own rules the whole time, even before either was named.

Outer-city logistics covers the journey from origin - factory, regional warehouse, often another country entirely - down to the ZEE boundary. For most of that distance, freight travels consolidated, by the large vehicle this project by now proved the public rarely sees stopping downtown, because it was never trying to. This half has one fixed endpoint, and only one: the break-bulk wall, the point where the load has to split before it can legally go any further.

This is where the hub sits, and where the mechanism this project in practice proposes does its real work: a microhub in reused dead space - viaduct underside, repurposed parking structure, existing market hall, never new excavation - run by a neutral third-party operator rather than any single carrier, so competitors never have to share sensitive data with each other, only with the operator. Financed with public capital at build, carrier fees at operation, not ongoing subsidy - the same pattern that's kept comparable real operators running for over a decade where permanently subsidized versions have historically failed. Every case-file precedent this project leans on - Gnewt Cargo, UCC Amsterdam, Mail Rail - sits inside this half of the system. None of them ever had to solve what happens on the street beyond the hub, because that was never their problem to solve.

Both constraints from the last two pages land here specifically. Siting: fixed once, at build time, and Better Bankside, City of London, and Beaugrenelle all proved it doesn't require new construction to get right. Grid capacity: also fixed once, and the same physical-ceiling logic applies - get the site's power supply wrong and there's no operational fix waiting on the other side of opening day.



The split - inner city

EVERYTHING AFTER THE WALL

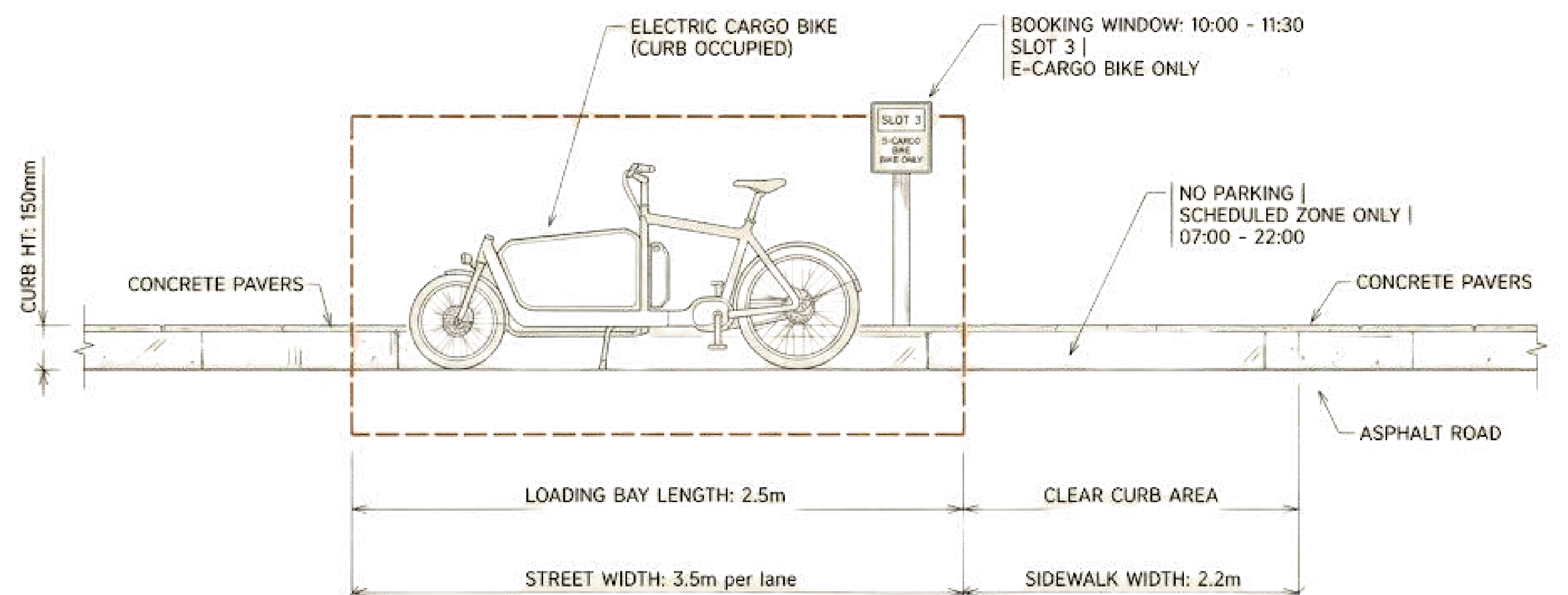
The outer-city half ends at one fixed point. This half starts there and never gets a second fixed point again - from the hub outward, everything is continuous, operational, and decided fresh every day rather than settled once at build time.

Cargo leaving the hub moves on smaller, zero-emission vehicles - cargo bike as the default, not a downgrade from something bigger, but the vehicle in practice suited to the job, the same logic. A van stays available, but only as a fallback, reserved for the specific case where a parcel genuinely doesn't fit on a bike. That ordering matters: default first, exception second, not a menu of equal options.

Both constraints from the electricity and space pages land here in their operational form, not their fixed form. Curb allocation: scheduled time-slot booking, adapted directly from dock-appointment systems by now standard in freight logistics - not invented for this project, just applied somewhere it hasn't been yet. And underneath that sits the piece this half carries that outer-city logistics doesn't: equity. Without a deliberate access mechanism, the same capital gap that by now locks independent shops out of ZEZ compliance - unable to absorb the cost of a compliant vehicle the way a large chain can - would lock them out here too, at the curb, for the exact same underlying reason. That's why this half also carries a reserved-access model alongside the routing logic, not as an add-on, but as a condition for the system in practice serving who it claims to serve.



One consequence worth naming plainly: this half has no equivalent to "get the site right once and it holds." Every day the hub runs, the curb has to be re-allocated, re-booked, re-negotiated. The system's long-term credibility depends on this half working continuously, not on a single decision made well at the start.



The method - how the search stayed open

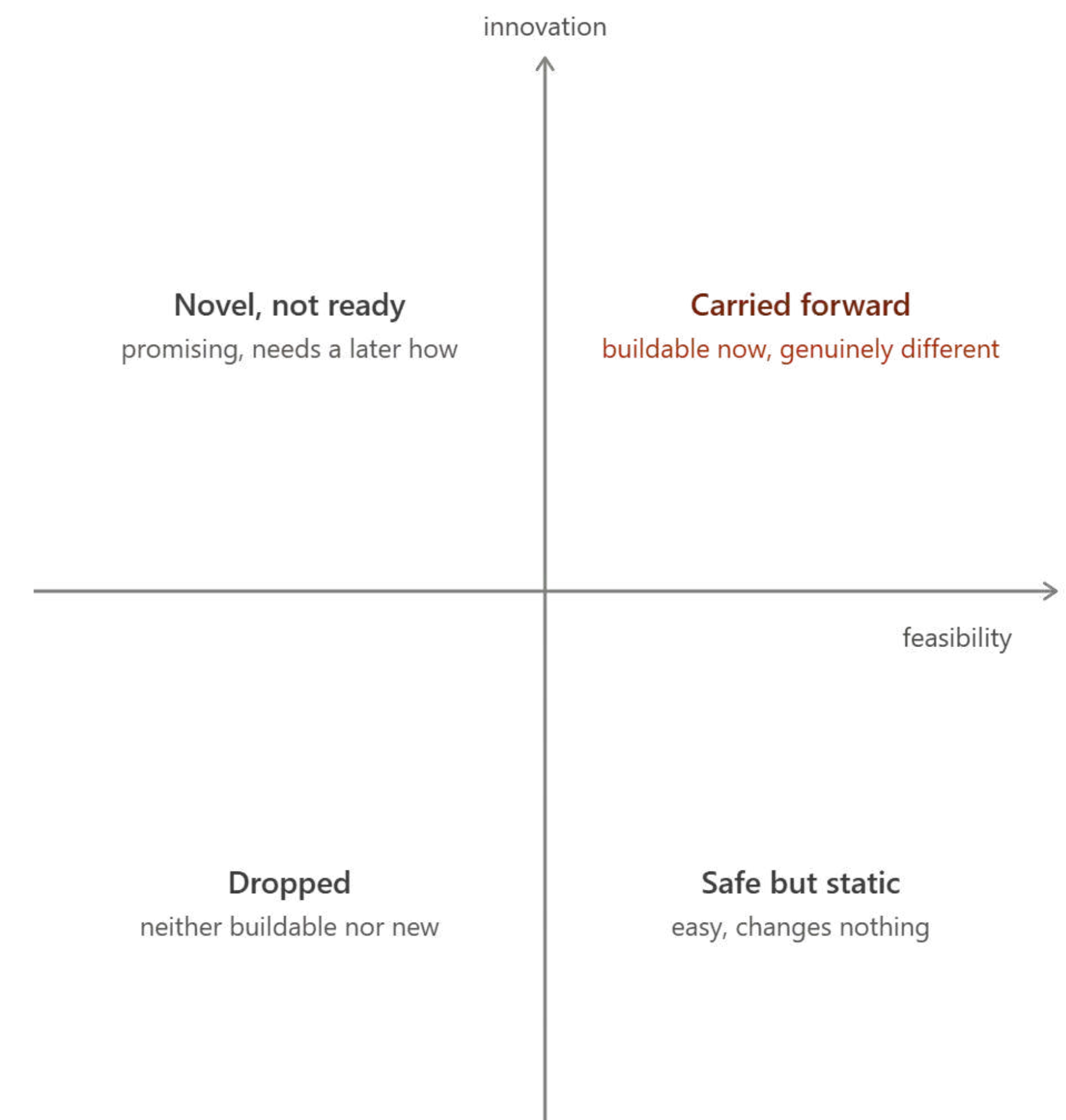
THE FAST QUESTION IS USUALLY THE WRONG ONE



The obvious way to open a project like this is to ask directly: how do we fix urban delivery congestion? That question feels neutral. It isn't. Framing a problem around finding a solution invisibly narrows the space of possible answers to whatever by now looks like a solution to the person asking, usually some version of what they by now know.

The difference matters more than it sounds like it should. Ask directly how to design a cheap product, and the question starts making decisions before any thinking happens - materials, technologies, and constraints get smuggled in by the phrasing itself, ruling out anything that doesn't by now fit that frame. Ask instead which materials are cheap and hold up well, and the goal hasn't changed at all, but the door stays open to answers that would never have survived the first version of the question.

Opening the question wide is only half the method. The more interesting half is what happens to narrow it back down without just picking whichever idea sounds best. Every answer generated this way gets placed on two axes, nothing more complicated than that: could this in practice be built today, and how far does it depart from how this is normally done. Plotted honestly, four kinds of answers emerge, not one ranked list. Some are safe and buildable but change nothing, useful as a fallback rather than a direction. Some are genuinely novel but not realistic yet, worth noting rather than discarding, since a later "how" question might close that gap. Some are neither, and get dropped outright. The ones worth carrying forward land high on both at once, buildable now and still a real departure from standard practice. The narrowing rule was never "which idea do I like" - it was which answers survive being checked against reality without losing what made them interesting.



Six candidate problem areas came out of the research that followed: curb and dock space, simultaneous power demand, small-shop access against large-chain competition, the empty return trip, data visibility between competing operators, and city zoning. Two were by design set aside, on purpose, not by oversight. Zoning reform is a thesis of its own, demanding expertise this project doesn't claim. Data visibility turned out not to be independent of the access question at all, so it got folded in rather than treated as a fifth thread pulling focus from the other four.

Four problems remained., each run through the same sequence on its own: a plainly worded, open question, an unfiltered round of ideas, then that same two-axis read applied independently before anything got compared across boards.

A genuinely complex problem is rarely complex because any single piece of it is hard. It's complex because holding all of it in your head at once is what overwhelms a person into not moving at all. Split it into pieces this by design, attack each on its own terms, and the answer is very often something that was by now there, just impossible to see while every problem was competing for the same attention at once.

The method - how the questions got written

STRIP EACH PROBLEM DOWN UNTIL IT
SOUNDS ORDINARY

How do we allocate scarce
curbsidde infrastructure
under variable demand?

how do you fairly
share a small
space everyone
wants at the
same time?

Once the four pressure points were isolated, each one got reduced to the plainest possible version of itself - no logistics vocabulary, no industry terms, just what a stranger might ask about the same underlying situation.

Curb and dock space, the way it in practice got asked: how do you fairly share a small space that everyone wants at the same time? Power demand: how do you handle everyone needing the same thing at once? Small-shop access: how does a smaller player get a fair shot next to a much bigger one? The empty return trip: why send something back with nothing in it?

Read on their own, any of these four could apply to a school cafeteria, a shared kitchen, a family business, a house move. That's the actual purpose of stripping the language this bare: a specific, technical question only lets specific, technical answers back in, while an ordinary one stays open to anything, since nothing in its phrasing tells your brain where to stop looking. Everything that came to mind counted as a valid answer at this stage - a mechanism borrowed from nature, a habit from daily life, a rule from an unrelated industry - with the only real discipline being to write it down before judging whether it made sense for a delivery van.

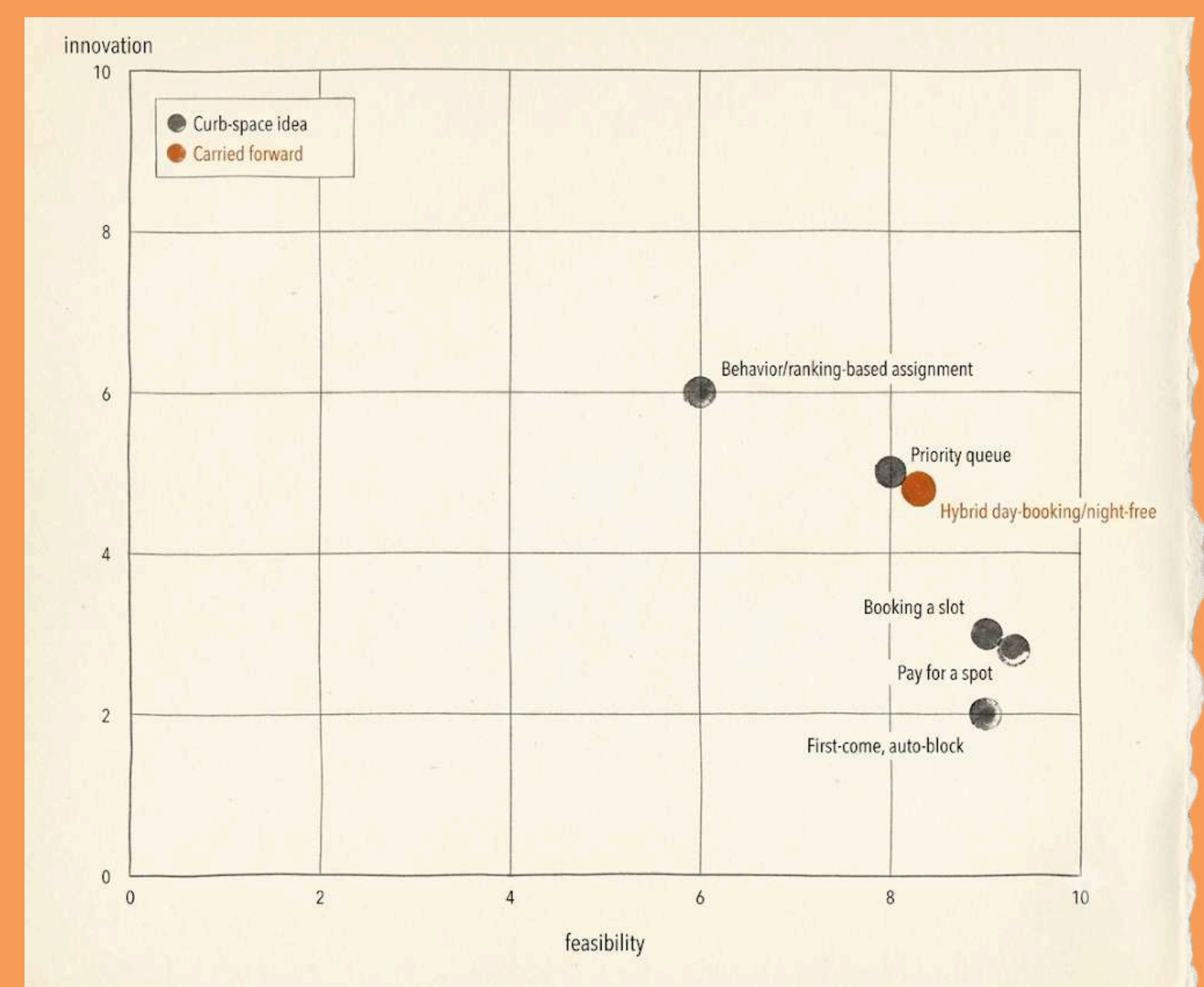
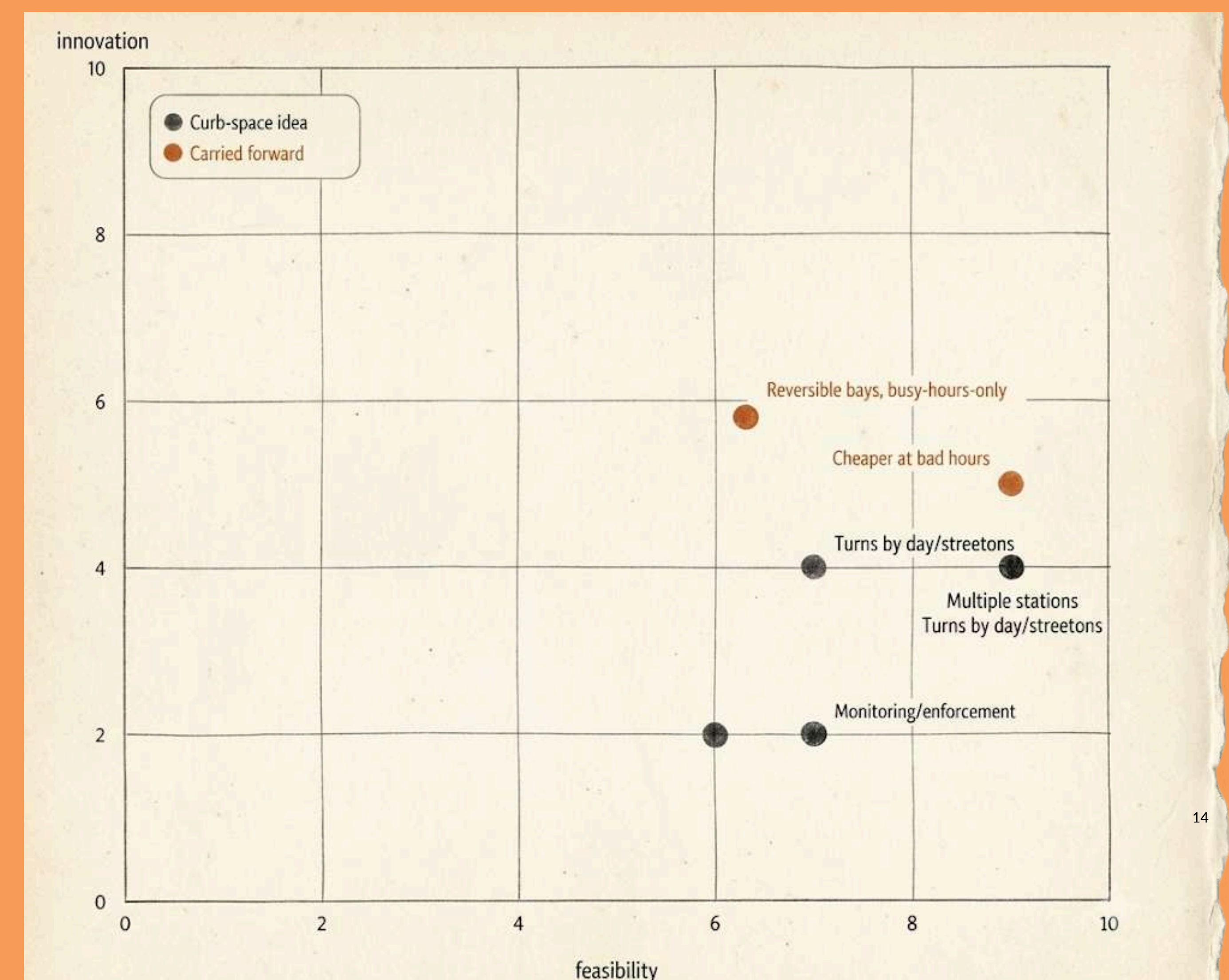


The method - the curb-space board, in full T W E L V E A N S W E R S T O O N E P L A I N Q U E S T I O N

Read the three carried-forward answers together rather than one at a time, and they're not three separate ideas - they're the same underlying move applied three different ways: don't add capacity; redistribute when the existing capacity gets used. Hybrid day-booking frees the space up overnight. Reversible bays free it up outside the busiest hours. Off-peak pricing makes leaving it for later in practice worth someone's while. None of these touch the physical curb at all. That's not a coincidence - it's the same insight the electricity pages make explicitly later: allocation is a scheduling problem, not a capacity problem, and this board arrived at that answer for curb space independently, before the project ever framed it that way in words.

Worth being honest about what the board doesn't show, too: the two highest-feasibility answers - first-come auto-block, and simple per-spot pricing - score lowest on innovation for a specific reason, not a weak one. They're by now what most cities do. That's precisely why they don't carry the project forward on their own; they're the baseline this method exists to beat, not a failure of the method to find something better.

One tension the diagram can't resolve by itself, worth naming rather than hiding: behavior or ranking-based assignment sits close to the carried-forward zone and looks tempting, but it requires tracking individual driver conduct over time - a data and fairness question this project hasn't taken on, and by design isn't picking up here.

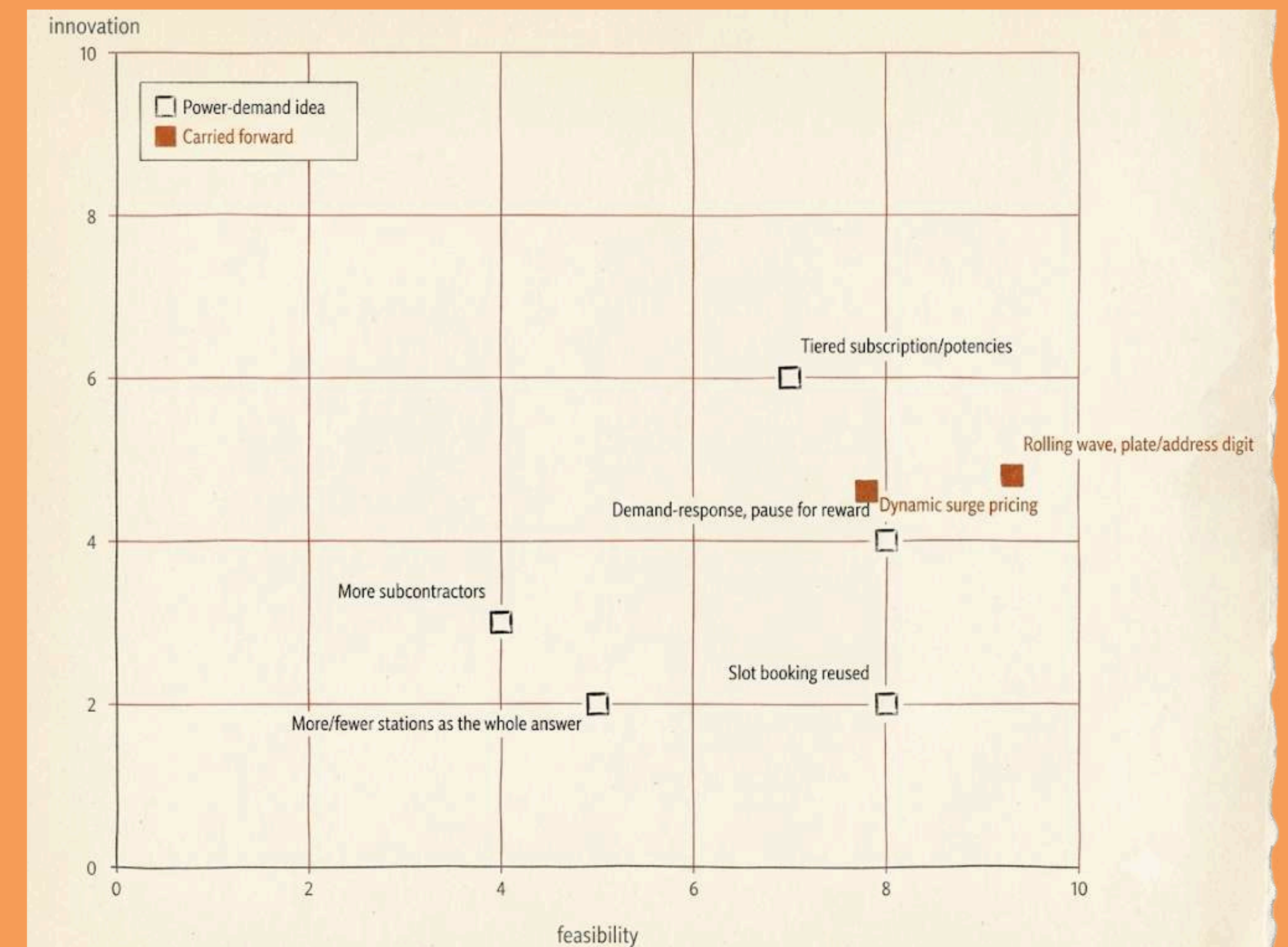
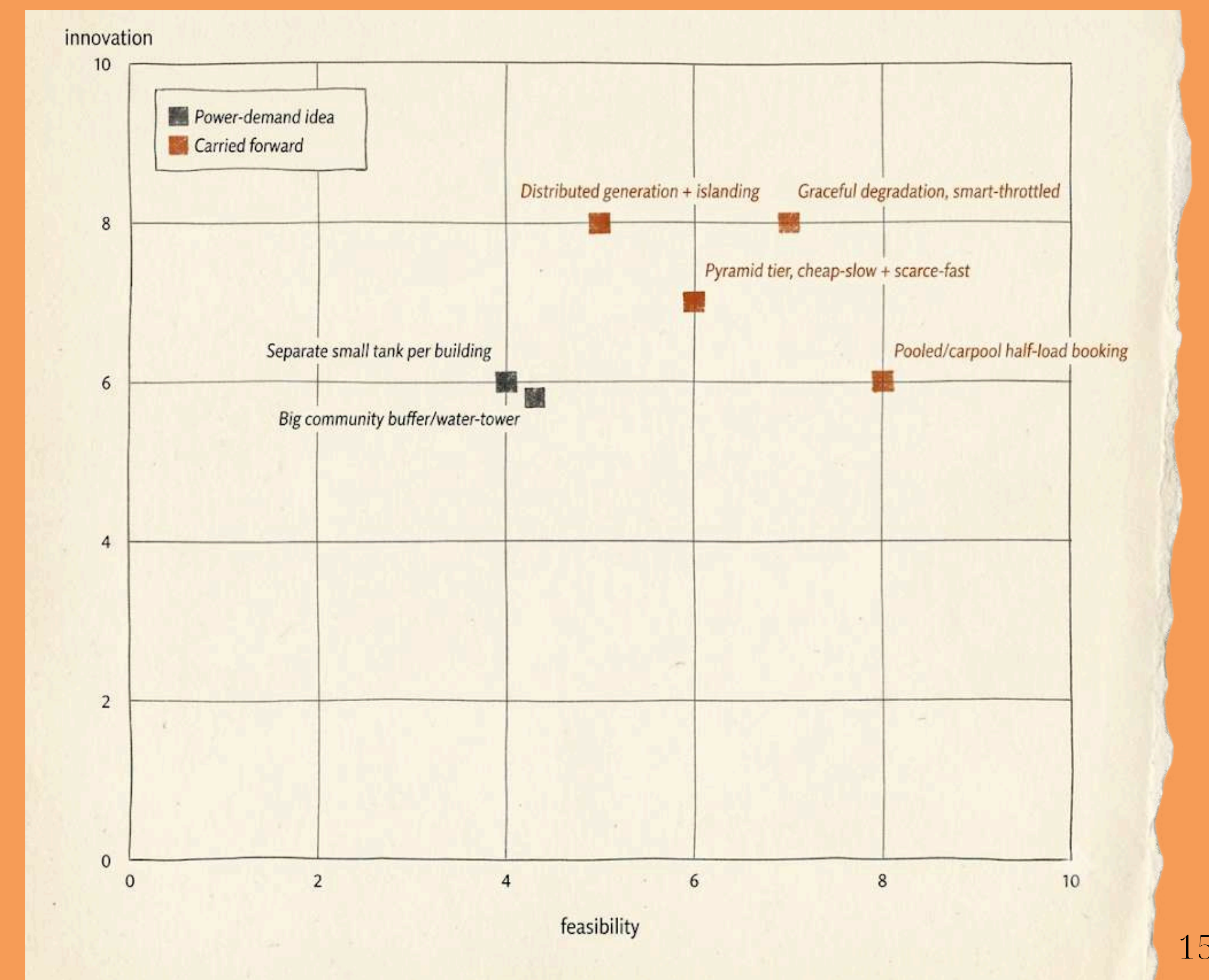


The method - the power-demand board, in full
THE SAME INSIGHT,
TESTED ON A
RESOURCE THAT CAN'T
BE RESCHEDULED BY A
SIGN

The curb board's answer was to redistribute when a fixed resource gets used, not to add more of it. Power demand is where that idea gets genuinely tested, because electricity doesn't respond to a painted line or a booking sign - the physical limit is real and immovable in a way curb space, on paper, technically isn't.

And the board still finds the same shape of answer. Distributed generation and islanding, graceful degradation under load, and pooled or carpooled charging all land in the carried-forward zone, and all three do the identical thing the curb board's winners did: they don't ask for more capacity, they change how existing capacity gets shared or absorbed under pressure. Graceful degradation in particular is worth sitting with - it's the highest-innovation answer on this entire board, and it's the direct, literal answer to the "what happens when demand exceeds supply" question the electricity mechanism page raises without naming a fix. This board found that fix before the project needed to ask for one.

Two answers are worth flagging as instructive failures, more than low scores. Separate small tanks per building and a big shared community buffer both score low on both axes - they're the passenger-EV playbook, borrowed wholesale from home charging, and they don't survive contact with fleet-scale demand at a single hub. And rolling wave charging, staggered by plate or address digit, is genuinely clever but scores lower on feasibility than its innovation would suggest - it depends on external administrative data this project doesn't control, which is precisely the kind of dependency the neutral-operator model was built to avoid needing.



The method - the moves-without-steering board, in full

THE LARGEST BOARD, AND THE ONE THAT SPLITS ITS WINNERS INTO TWO DIFFERENT KINDS

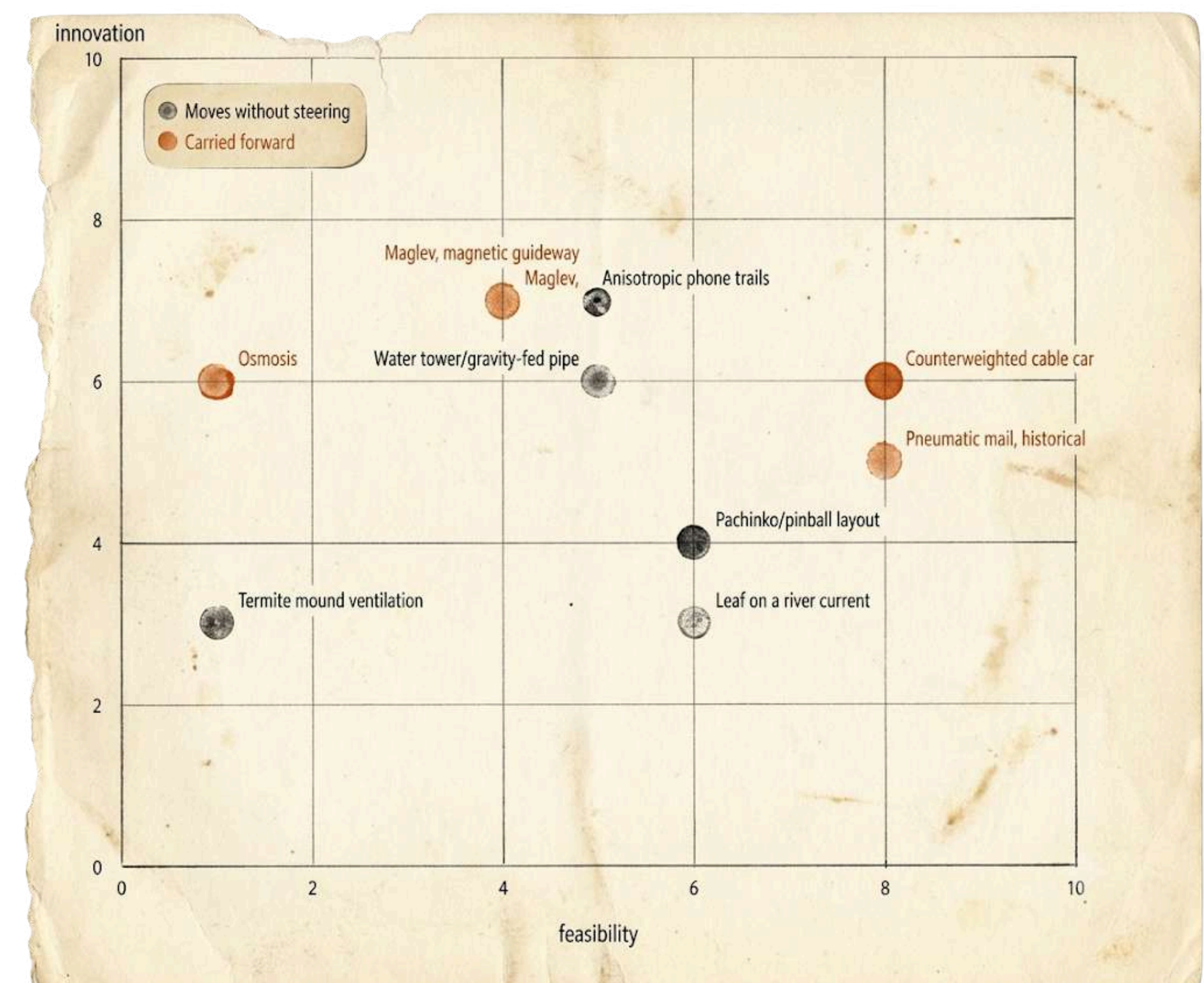
Eighteen answers to the same plain question - how does something move without anyone steering it - spread across both parts of this board, and it's the widest single board in the whole exercise. Worth reading the four marked answers carefully, because unlike the curb and power boards, they don't all land in the same place, and that difference matters.

Counterweighted cable car and pneumatic mail both sit high on feasibility and innovation at once - the same clean win pattern as everything carried forward so far. Osmosis and maglev don't. Both score high on innovation but low on feasibility, sitting in the region the earlier quadrant diagram calls "novel, not ready" rather than "carried forward." They weren't kept because they're buildable now. They were kept because gravity-and-guidance as a category of answer clearly kept recurring across the board, and it seemed worth holding onto that direction even where a specific mechanism wasn't ready to act on yet.



That distinction turned out to matter for what in practice got built. The counterweighted cable car's gravity-pulls-the-other-side principle is the one that survived into the final mechanism, paired later with the bucket elevator from the narrow-channel board. Pneumatic mail supplied the historical proof that an enclosed, driverless, single-purpose system can run for decades without failing. Osmosis and maglev didn't make it into the physical build, but they're worth naming honestly rather than invisibly dropping, since good ideas that aren't ready yet are still evidence the method is finding real directions, more than filling a board.

Most of the rest of the board sits low on both axes, and that's expected here more than on any other board - asking "how does something move without a driver" pulls in a lot of genuinely universal answers (gravity, pressure, a conveyor belt) that are true everywhere and interesting nowhere in particular for this specific problem.

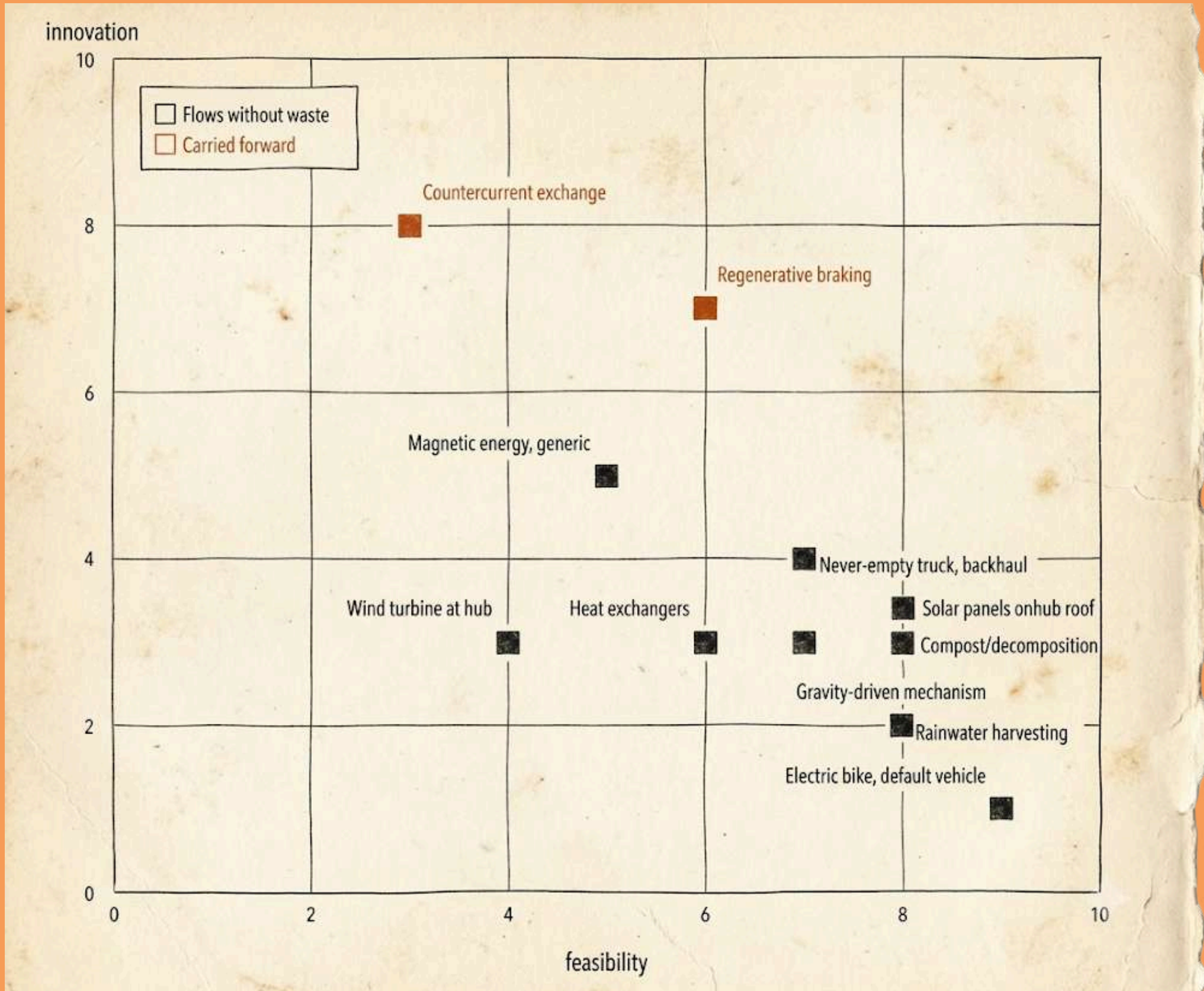


The method - flow and throughput, the two smaller boards

THE TWO BOARDS THAT FINISHED THE MECHANISM

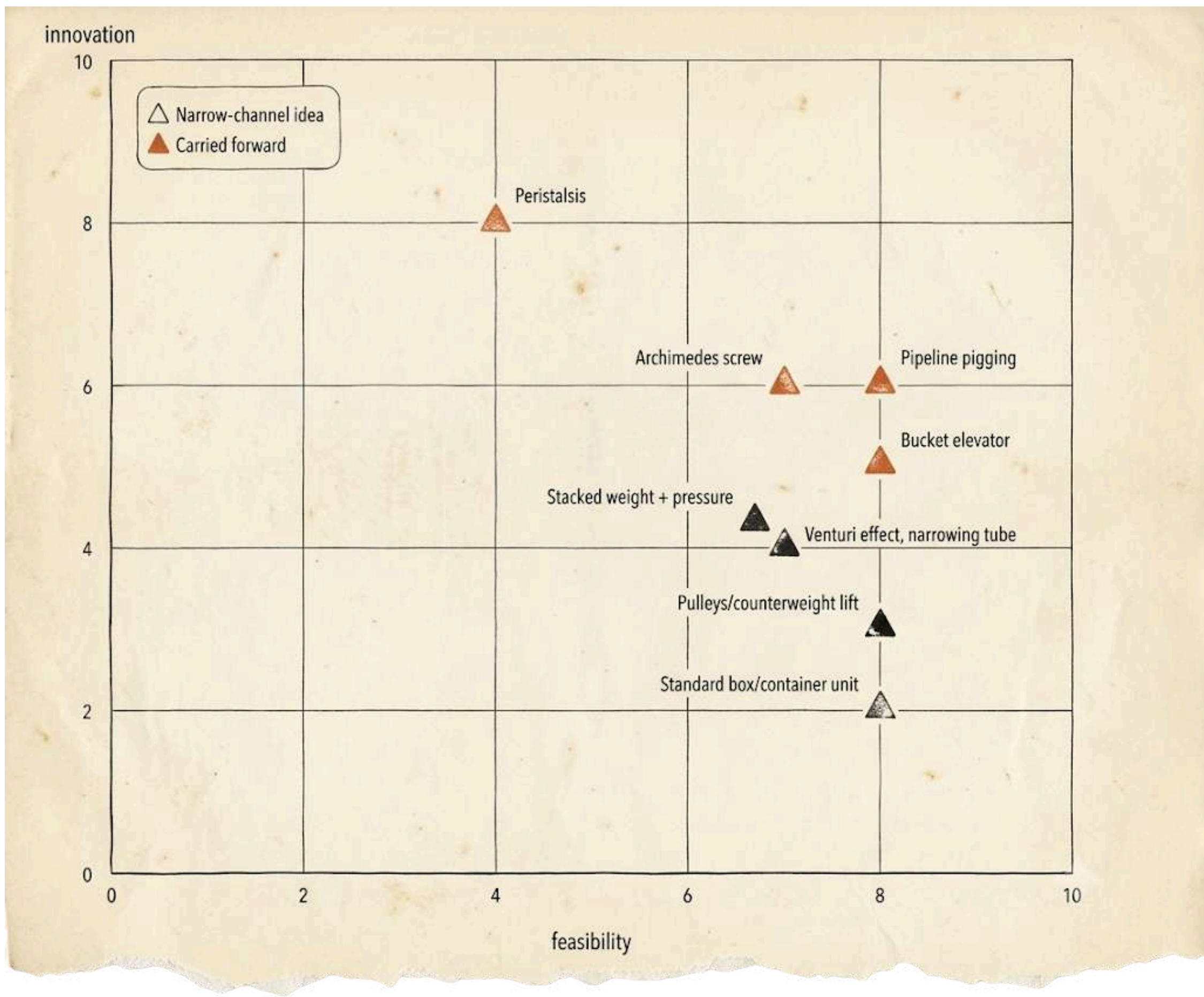
Flow-without-waste and narrow-channel-throughput are the two smallest boards, eleven and eight answers respectively, and between them they carried the largest share of what in practice got built. Worth reading them together rather than separately, since that's genuinely how they ended up being used.

Regenerative braking is the only answer carried forward from the flow board, and it's carried forward for a specific reason worth stating plainly: it wasn't chosen, it fell out for free. Once the counterweighted mechanism from the steering board was by now decided - a loaded carrier descending, decelerating at each stop - the energy that deceleration produces was by now there, waiting to be captured or wasted. Regenerative braking didn't add a new system to the design. It just stopped that energy from being thrown away. Countercurrent exchange sits in the same "novel, not ready" territory as osmosis and maglev from the previous board - a genuinely interesting principle, borrowed from how fish gills conserve oxygen, that never found a concrete mechanical form for this specific problem.



The narrow-channel board did more of the actual construction work than any other. Four of its eight answers were carried forward, the highest hit rate on any board in this project - pipeline pigging, Archimedes screw, bucket elevator, and peristalsis all cleared both axes at once. Bucket elevator is the one that mattered most: paired with the counterweighted cable car from the steering board, it supplies the physical structure the whole mechanism runs on - standardized containers riding one continuous loop, loading and unloading themselves at each end. Pipeline pigging and Archimedes screw stayed as backup mechanisms, options for a flat site with no elevation to draw on. Peristalsis, the single highest-innovation answer across all three tube boards, never made it into the physical build - nothing off-the-shelf replicates a squeezing wave, and building one from scratch wasn't a fight worth picking for a nine-day project.

Read across all three boards together, one thing holds: every genuinely strong answer, on every board, ended up either directly building the mechanism or explaining why the mechanism works the way it does. Nothing scored high and then sat unused.



The evidence

SIX PLACES HAVE BY NOW TESTED PIECES OF THIS SYSTEM

Before committing to a final mechanism, the two surviving clusters - truck sharing, slot booking - needed testing against reality: had anyone in practice tried to build something like this before? Five documented cases, spanning both halves of the wall this project splits apart, gave real implementation lessons to design against, rather than a blank page.

London - Mail Rail, 1927–2003. Dedicated underground rail for mail and parcels, fully automated, single operator, no competitor coordination required because there was only ever one tenant. 76 years of continuous operation, closed by choice, not failure. Lesson taken: narrow scope and a single operator is what makes an automated system last.

Paris - Beaugrenelle, ongoing. An underused underground parking structure converted into a sorting hub for Chronopost. No new excavation. Lesson taken: reused dead space, not new construction, is the real-estate decision that in practice holds.



Switzerland - Cargo Sous Terrain, 2016–halted September 2025. Automated underground freight tunnel network, national scale, multiple hubs. Roughly a decade and \$3 billion committed to phase one before the federal government, the cantons, and the city of Zurich suspended it. Lesson taken: broad, ambitious, multi-site networks fail on siting and politics, not engineering - precisely why this project stayed small and phase-gated instead.

London - Gnewt Cargo, 2009–ongoing. A neutral third-party operator serving multiple carriers on one shared electric fleet, so competitors never share data with each other, only with the operator. Public seed funding at launch; running on carrier fees for over a decade since. Lesson taken: this is how the competitor-data problem in practice gets solved in practice, and how a hub survives without permanent subsidy.

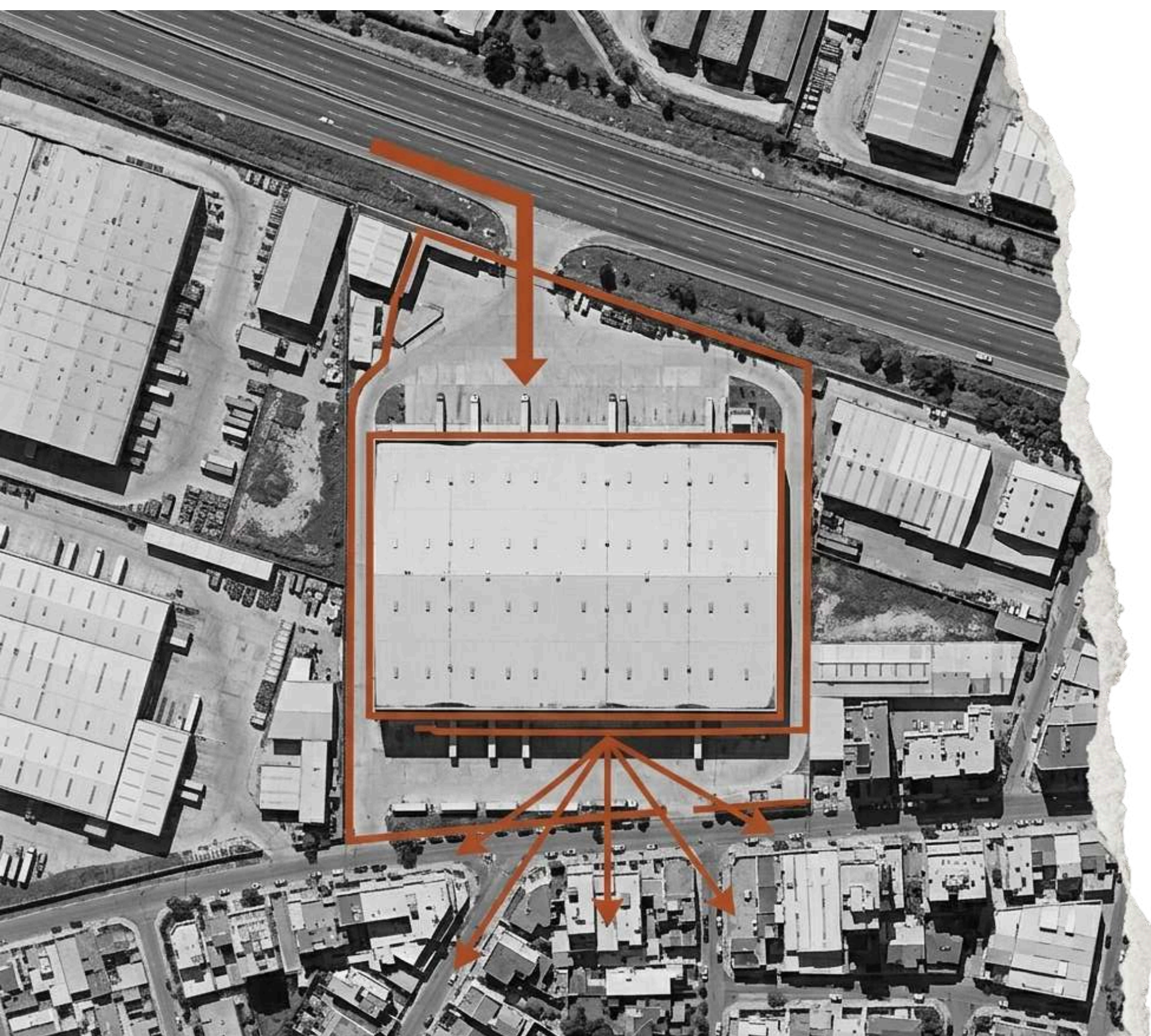
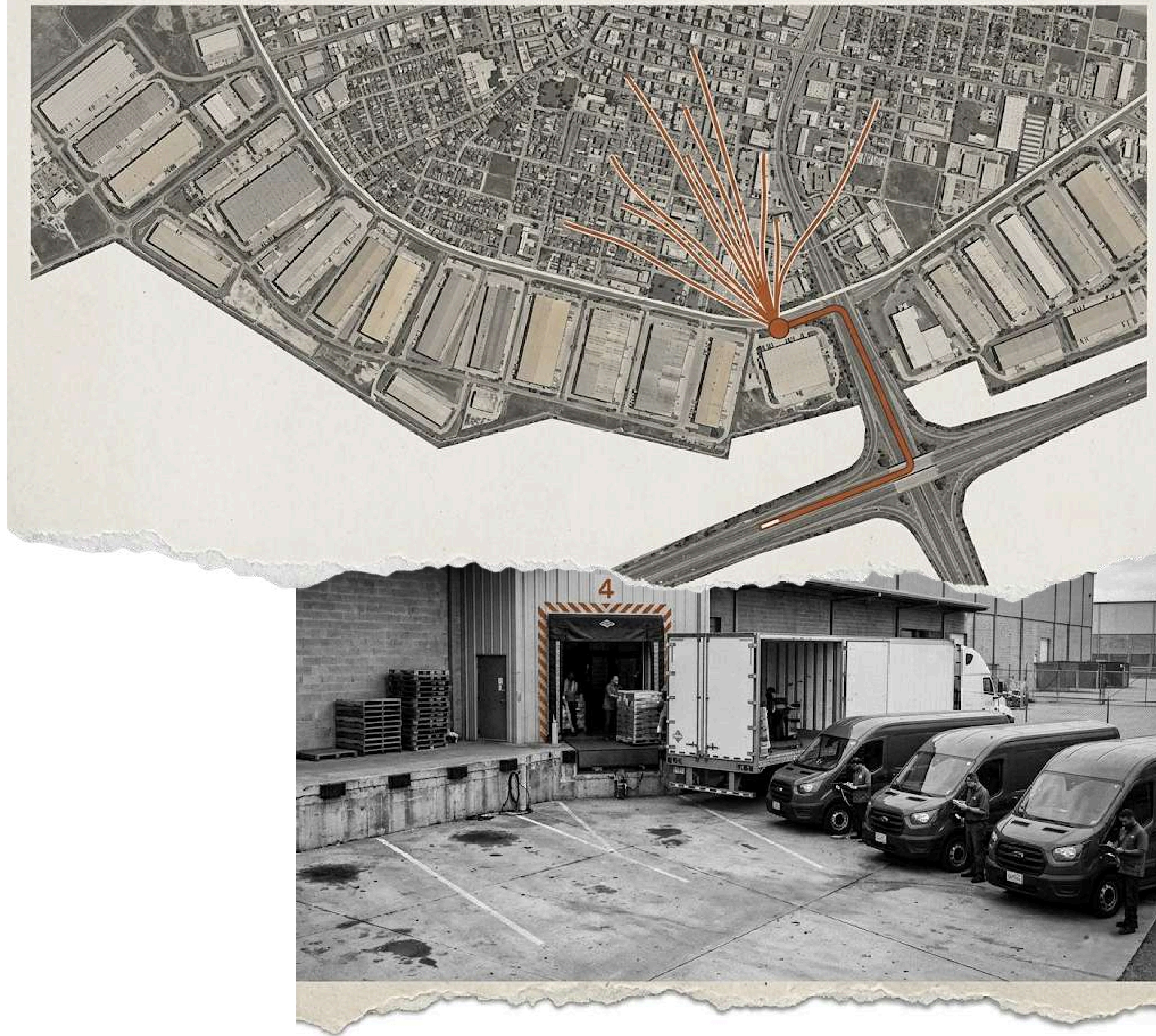
Amsterdam - UCC Amsterdam, 2013–ongoing. A working consolidation model operating inside the strongest, most enforced zero-emission regulation anywhere in Europe.

Nijmegen - city-run consolidation, 2000s–ongoing. When nobody else would build it, one city official merely built it herself. A one-year grant covered the first year of operations, buying time to sign shops and carriers before the idea had proven itself - but the free ride nearly became its own trap, since convincing anyone to start paying once the subsidy ended was a separate, harder fight than getting them to sign up in the first place. It survived that transition and is still running, well over a decade later. Lesson taken: a launch subsidy¹⁸ only works if the operator is by now building toward the moment it disappears, not treating free as the plan.

The system - layer 1 of 3: the boundary hub

WHERE THE TRUCK IN PRACTICE STOPS, AND WHY THAT'S NOT INSIDE THE CITY

The main hub sits at the ZEZ boundary, not embedded in a residential street-industrial or logistics park land, by now zoned for precisely this kind of use. Real precedent backs the choice: Barcelona's and Stockholm's HALLO pilots by design placed their consolidation centers in municipalities on the border of their low-emission zones rather than inside them, keeping the hub reachable by conventional trucks that never need to cross into the restricted zone at all.



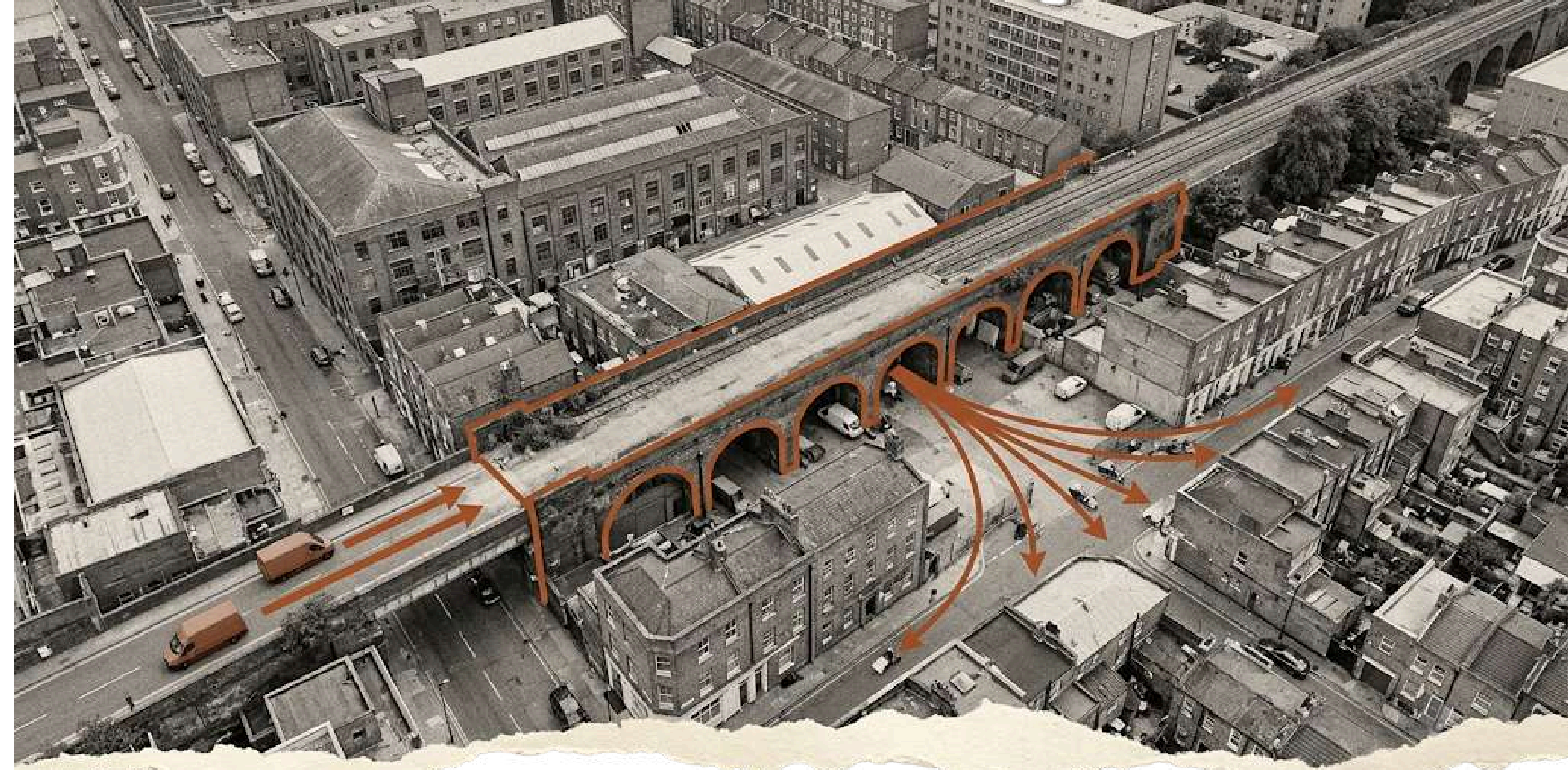
This is where break-bulk in practice happens - one large truckload arrives, gets sorted by destination, and reloads onto the smaller zero-emission vehicles that carry it onward. Run by a neutral third-party operator, not any single carrier, so competitors hand off to one trusted party instead of sharing sensitive data with each other. Financed with public capital at build, carrier fees at operation-never ongoing subsidy-is the pattern that's kept Gnewt Cargo and UCC Amsterdam running for over a decade where permanently subsidized versions have collapsed.

The system-layer 2 of 3: the micro hub S M A L L , E M B E D D E D , A N D N E V E R B U I L T N E W

Between the boundary hub and the final curb sits a second, smaller layer: microhubs, sited inside the city, close to real demand, in space that by now exists rather than space built for the purpose. A reused railway viaduct arch, an underused parking structure, an existing market hall - the same reuse logic Beaugrenelle and Better Bankside by now proved at working scale, no new excavation required.

This is what makes a microhub safe to sit on a lived-in street in a way the main hub isn't: nothing arriving here is larger than a van, and most of what leaves is a cargo bike. The trucks stopped two layers back, at the boundary. A microhub's job is narrower and more local - receive from the main hub, sort by immediate neighborhood, hand off to the smallest vehicle that can finish the job.

This hub is the first of three connected layers; what it can't reach on its own is precisely what the next two exist to solve.

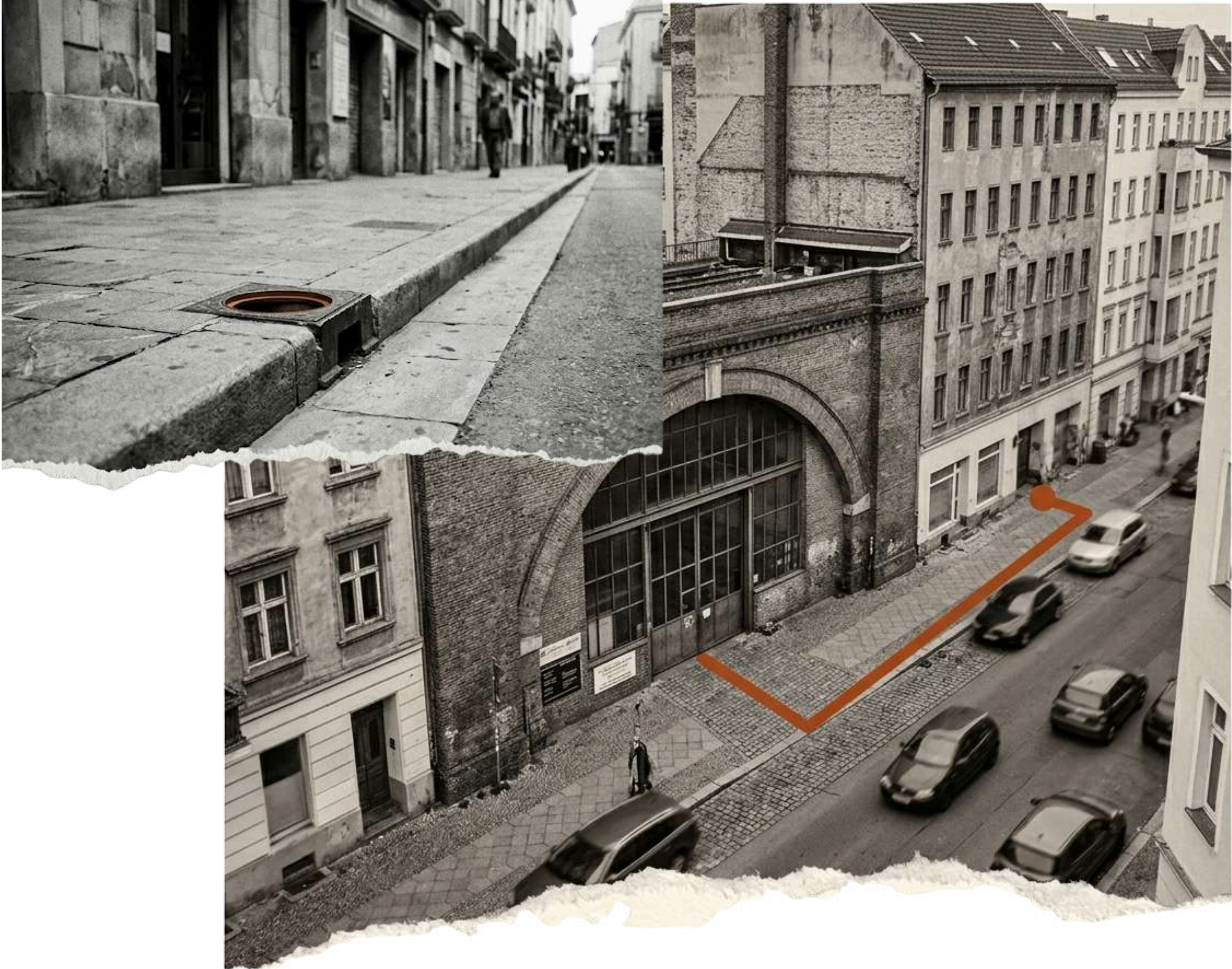
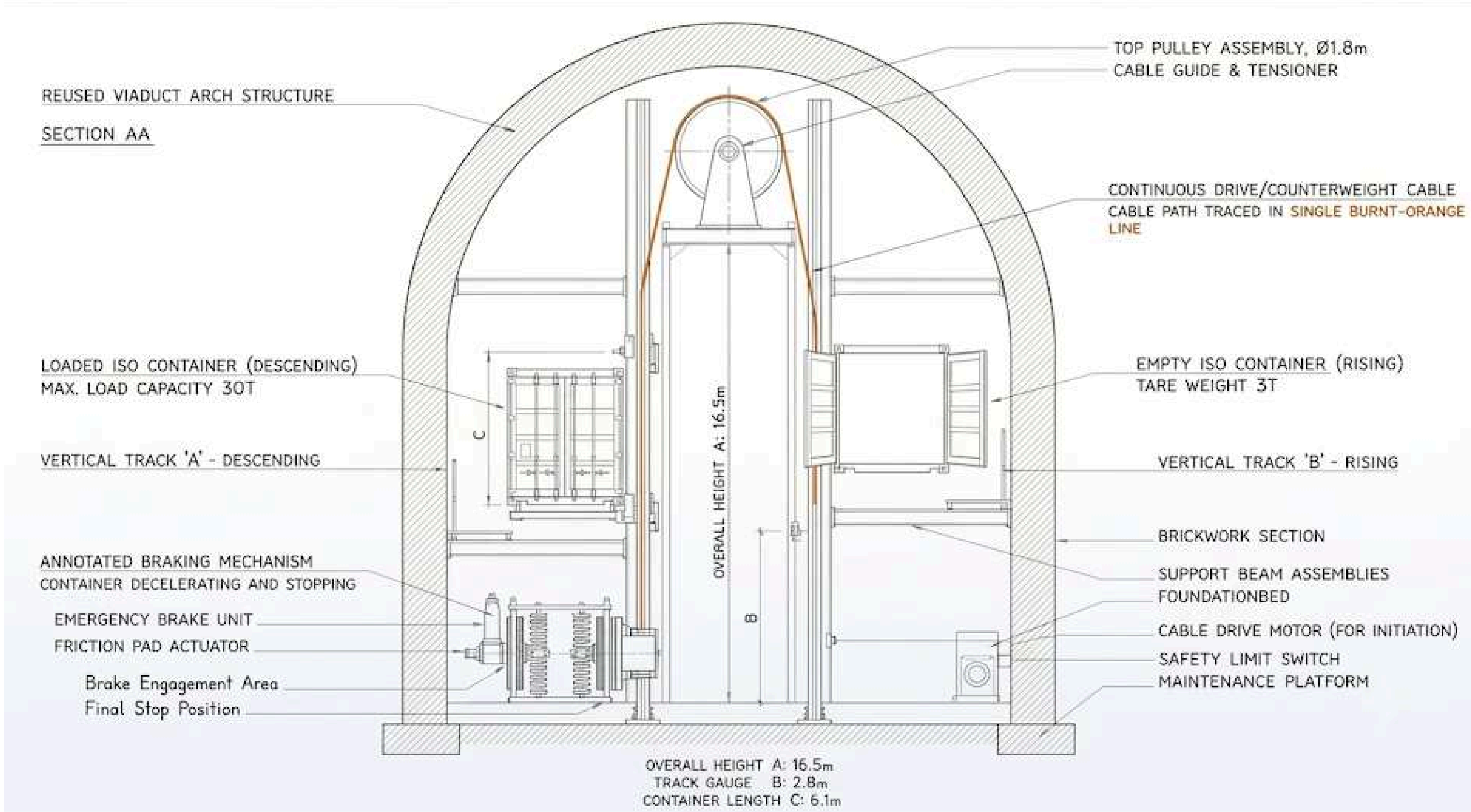
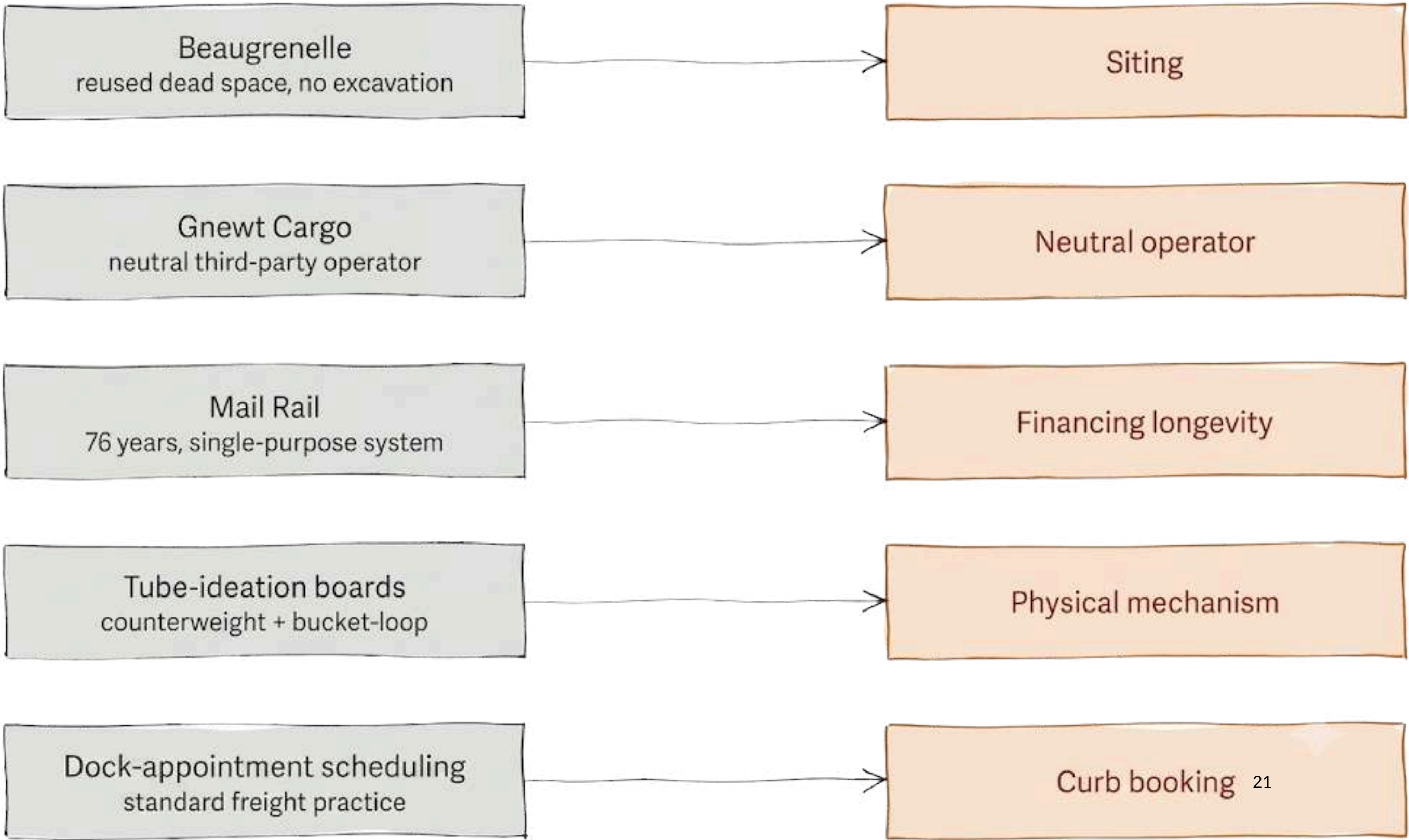


The system - layer 3 of 3, the last stretch

THE SYSTEM - THE LAST STRETCH

The short link between a microhub and its nearest curb runs on a counterweighted loop, the same physics as a funicular - a loaded container descending pulls an empty one back up on the same cable, gravity doing most of the work rather than a motor running constantly. Standardized containers ride it the way a bucket elevator carries material through a shaft, loading and unloading themselves at each end. Regenerative braking isn't a separate addition; it falls directly out of a container decelerating at every stop, capturing energy that would otherwise be lost.

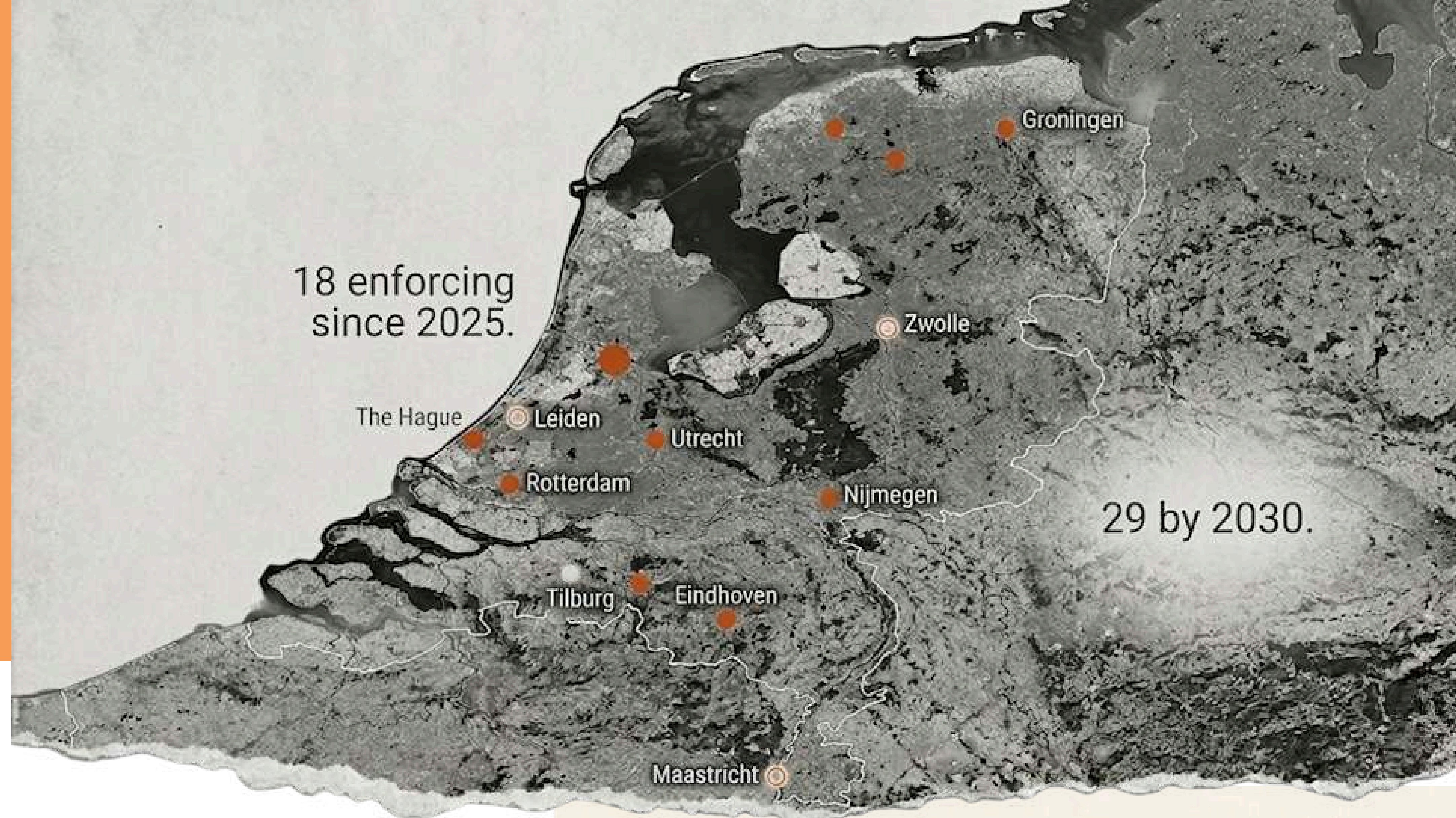
At the curb, the system becomes a scheduling problem, not a construction one: time-slot booking, adapted from dock-appointment scheduling by now standard in freight logistics, replacing first-come competition for the same limited stretch of curb. Underneath that scheduling sits the equity mechanism this system exists to protect - reserved access for small shops, so the same capital gap that by now locks them out of ZEZ compliance doesn't lock them out here too.



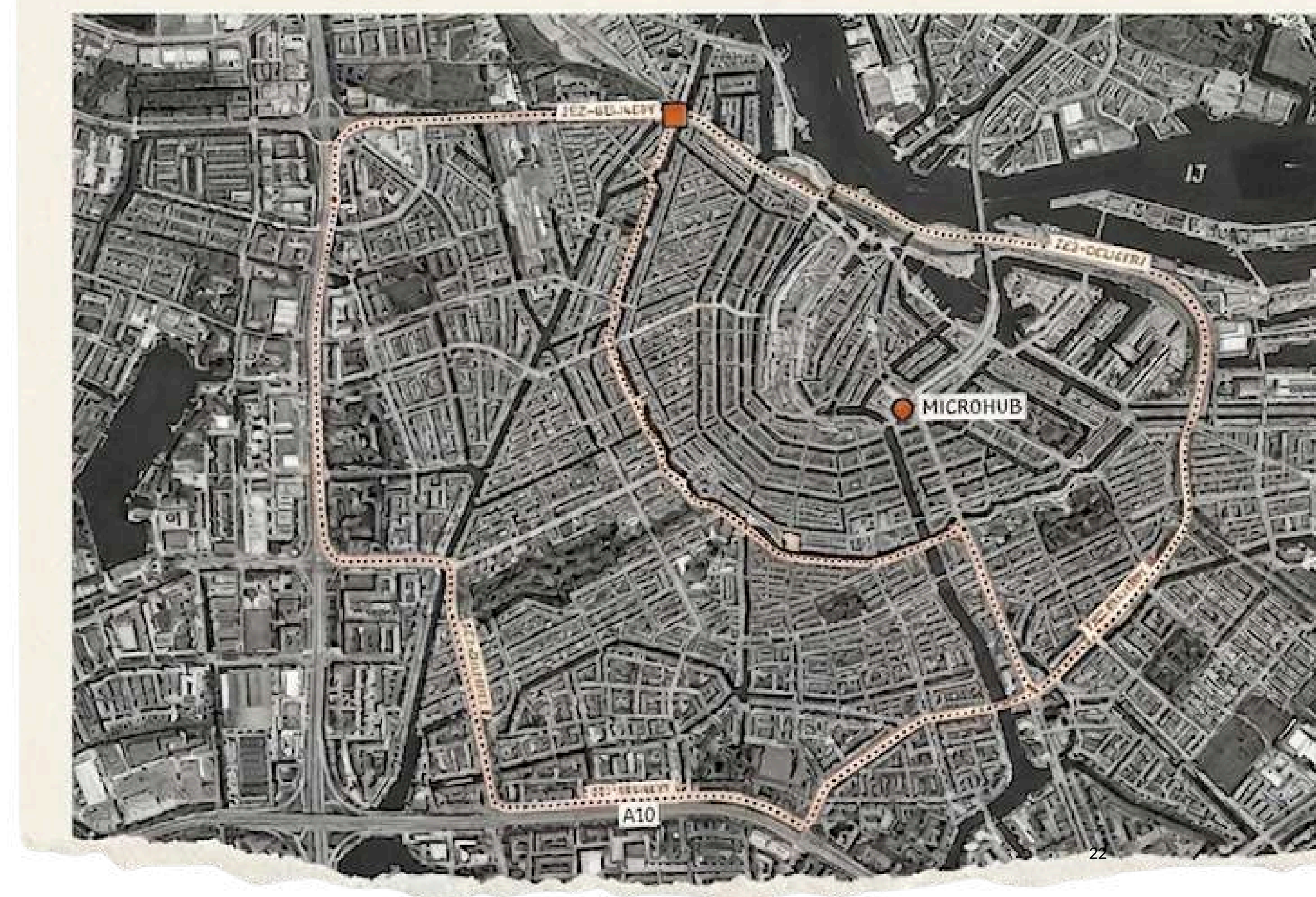
The site
WHERE A
WORKING
MODEL BY
NOW MEETS
THE
STRONGEST
ENFORCEMENT

Every case file so far has been evidence from somewhere else. This is where the project stops citing precedent and commits to a real, specific place-because a three-layer system like this only means something once it's checked against real conditions, not argued in the abstract.

Amsterdam is the one place among everything researched where a working consolidation model and the strongest active zero-emission enforcement in Europe by now sit in the same city. The Netherlands has 18 cities enforcing zero-emission zones since January 2025, expanding to 29 by 2030-not a projection, but a live national rollout. Within one year of enforcement beginning, battery-electric van registrations rose from 11% to 78% of new registrations nationally, among the fastest documented fleet conversions anywhere. UCC Amsterdam has been running inside this exact regulatory environment since 2013, and Nijmegen, elsewhere in the same country, proved a city-led consolidation model can survive its own subsidy cliff and still be running well over a decade later.



That combination is the actual argument for Amsterdam, stated precisely: not "a nice European city with bike lanes," but the one place where this project's central bet - that ZEZ enforcement, not voluntary goodwill, is what makes shared infrastructure stick - is by now measurably true, on the ground, right now. What follows from here is the pilot scale of this system specifically: one boundary hub, one microhub, one connector, sized for one district. The larger claim - that this same three-layer logic scales to other cities running the same regulation - gets its own argument next, rather than being assumed here.



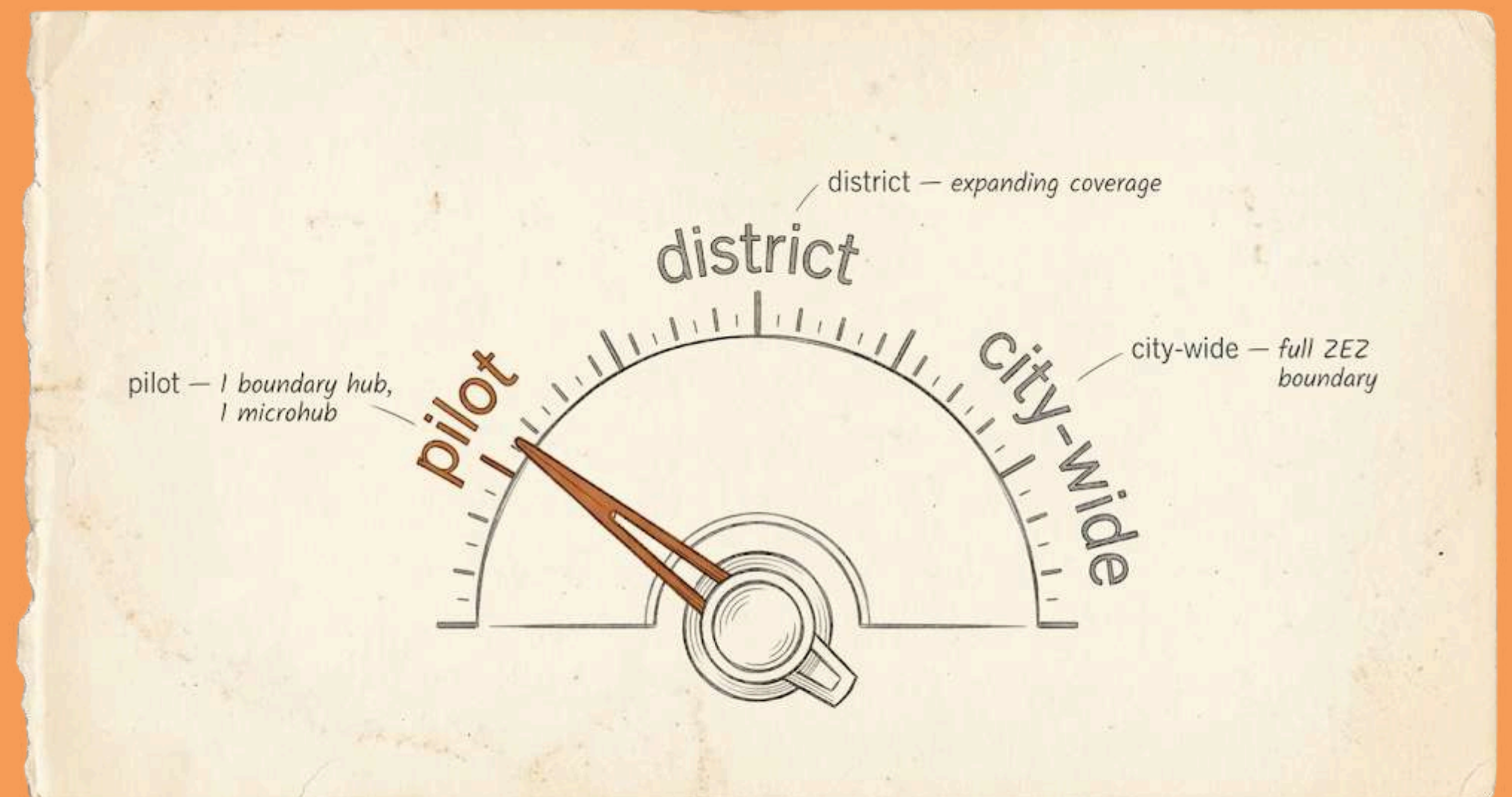
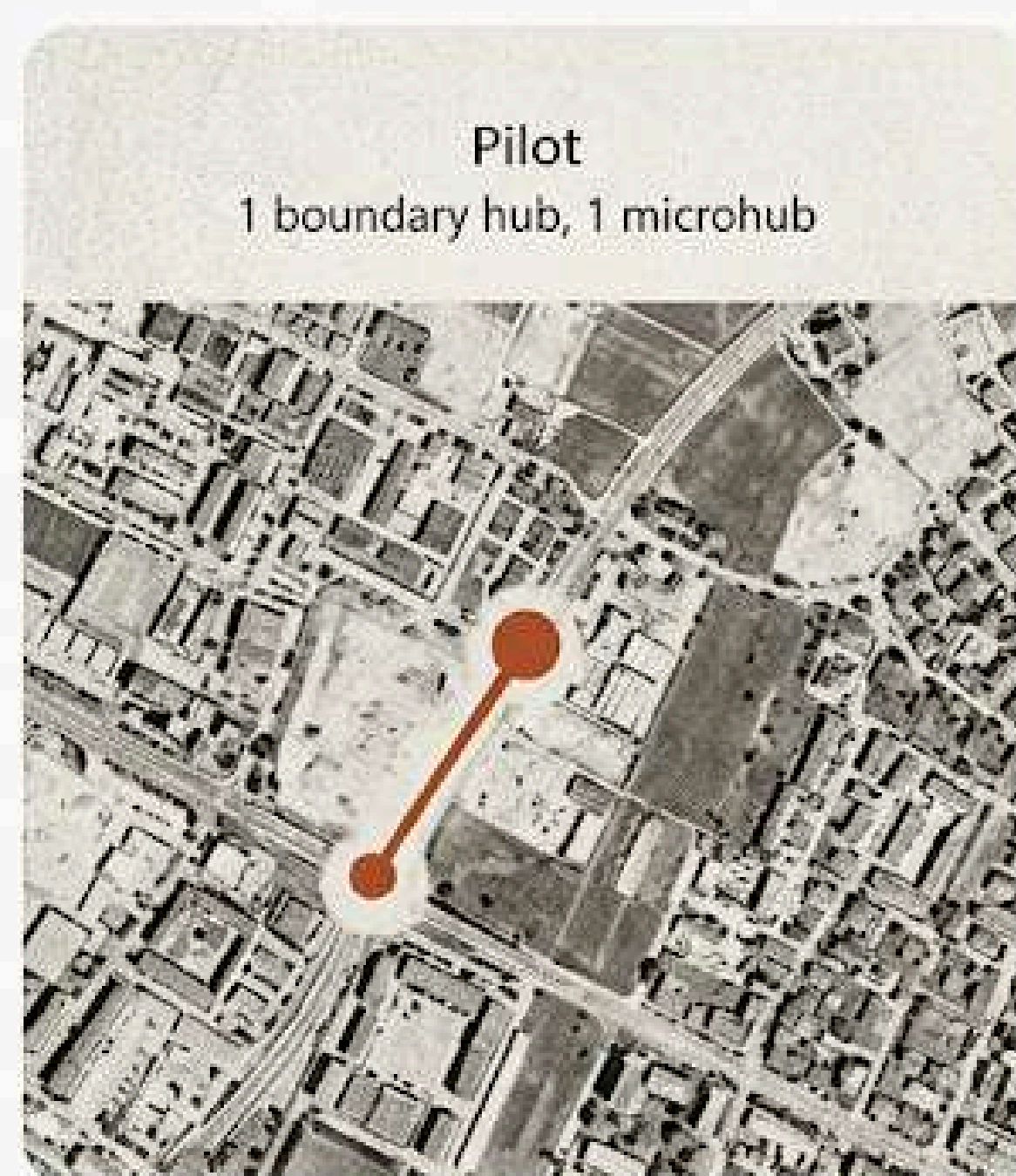
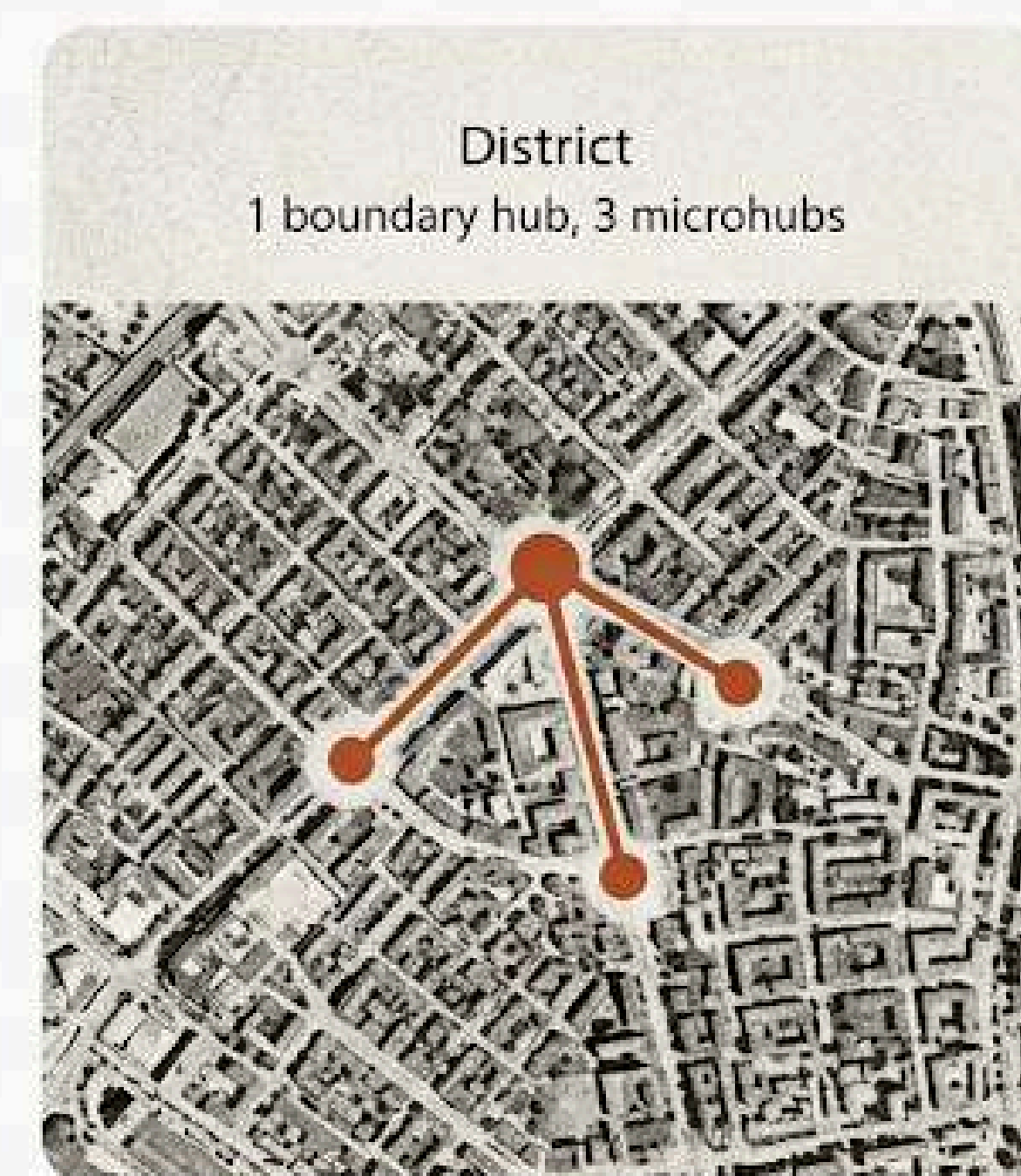
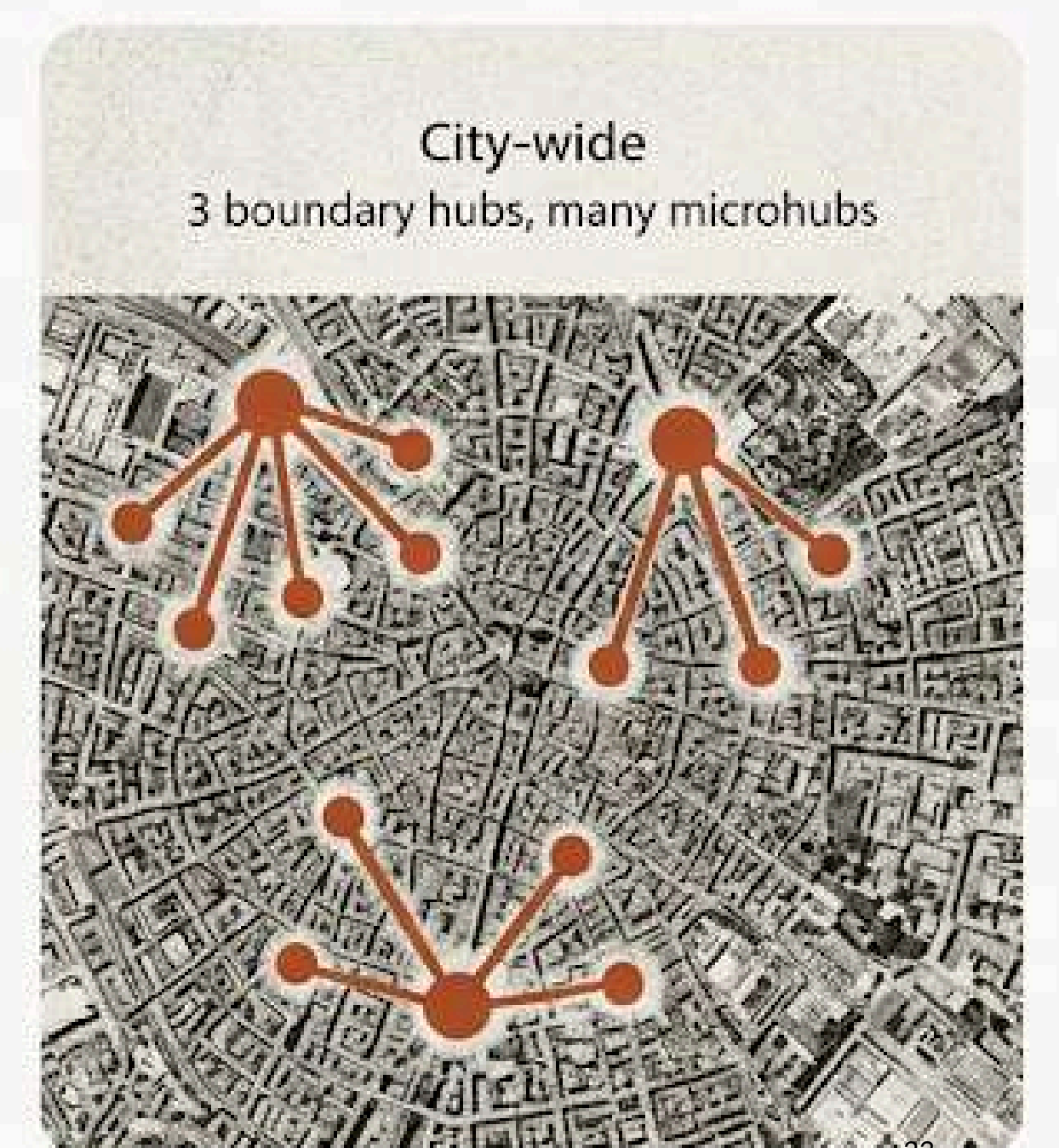
The system - read as one

THREE LAYERS, ONE FLOW, SIZED BY A DIAL, NOT FIXED BY A BLUEPRINT

Everything from the boundary hub through the connector to the curb is one continuous flow, not three separate good ideas sitting next to each other: a truck arrives at the city's edge, break-bulk happens once, smaller vehicles carry consolidated loads to a microhub closer to demand, and the last short stretch to a specific curb runs on the counterweighted link - each layer picking up precisely where the one before it stops being able to reach any further. What the boundary hub can't do, the microhub does. What the microhub can't do without another van trip, the connector does. Nothing in this project was designed as a single object; it was designed as a handoff, three times over.

And every size decision in that flow is a dial, not a fixed number. One boundary hub and one microhub, sized for a single pilot street, is what this project in practice proposes and argues for. It is not the ceiling. The same three-layer logic - reused space for siting, a neutral operator for financing, a counterweighted link for the last stretch - scales precisely the way a city's own ZEZ enforcement scales: more microhubs as more districts come under pressure, without ever requiring a new tunnel network or a redesigned mechanism, because the mechanism was never coupled to a fixed city size in the first place.

That's the honest scope of the claim, stated once and plainly: proven at pilot scale, in one city, against one specific set of case files. Structurally transferable to any of the other 28 Dutch municipalities running the identical regulation by 2030, and beyond that, to any European city whose own version of the Green Deal produces the same break-bulk wall this project started by naming.



Stakeholders - who transacts through the system

TWO VERY DIFFERENT REASONS TO USE THE SAME HUB



Small shops gain access they currently can't afford, more than convenience.

The capital gap by now established early in this project - a compliant electric vehicle costs roughly 2-3x a diesel equivalent, easily absorbed by a large chain, often decisive for an independent shop - is the same gap that would exclude them from this system too, without a deliberate counter-mechanism. Reserved booking access, priced or allocated on an asymmetric basis rather than flat first-come terms, is that mechanism. The economic case beyond mere access is real: reclaimed street frontage has been shown to increase purchases by roughly 50% where cities have tried it - worth verifying against a primary source before this goes on the final board, but directionally strong. What they lose, honestly: dependence on a shared schedule rather than full control over their own delivery timing, the same trade every participant in a consolidated system accepts.

Carriers gain compliance and reduced coordination cost, and lose direct control over the last stretch of their own deliveries.

A neutral third-party operator - the Gnewt Cargo, UCC Amsterdam pattern - means competing carriers hand off to one trusted party rather than exposing route and volume data to each other, solving the exact horizontal-collaboration problem that's killed most shared consolidation attempts historically. Buy-in isn't asked for on trust: ZEZ enforcement by now removes the free alternative of driving in directly, so using the hub stops being optional goodwill and becomes the path of least resistance to staying compliant at all.



2 spaces reserved

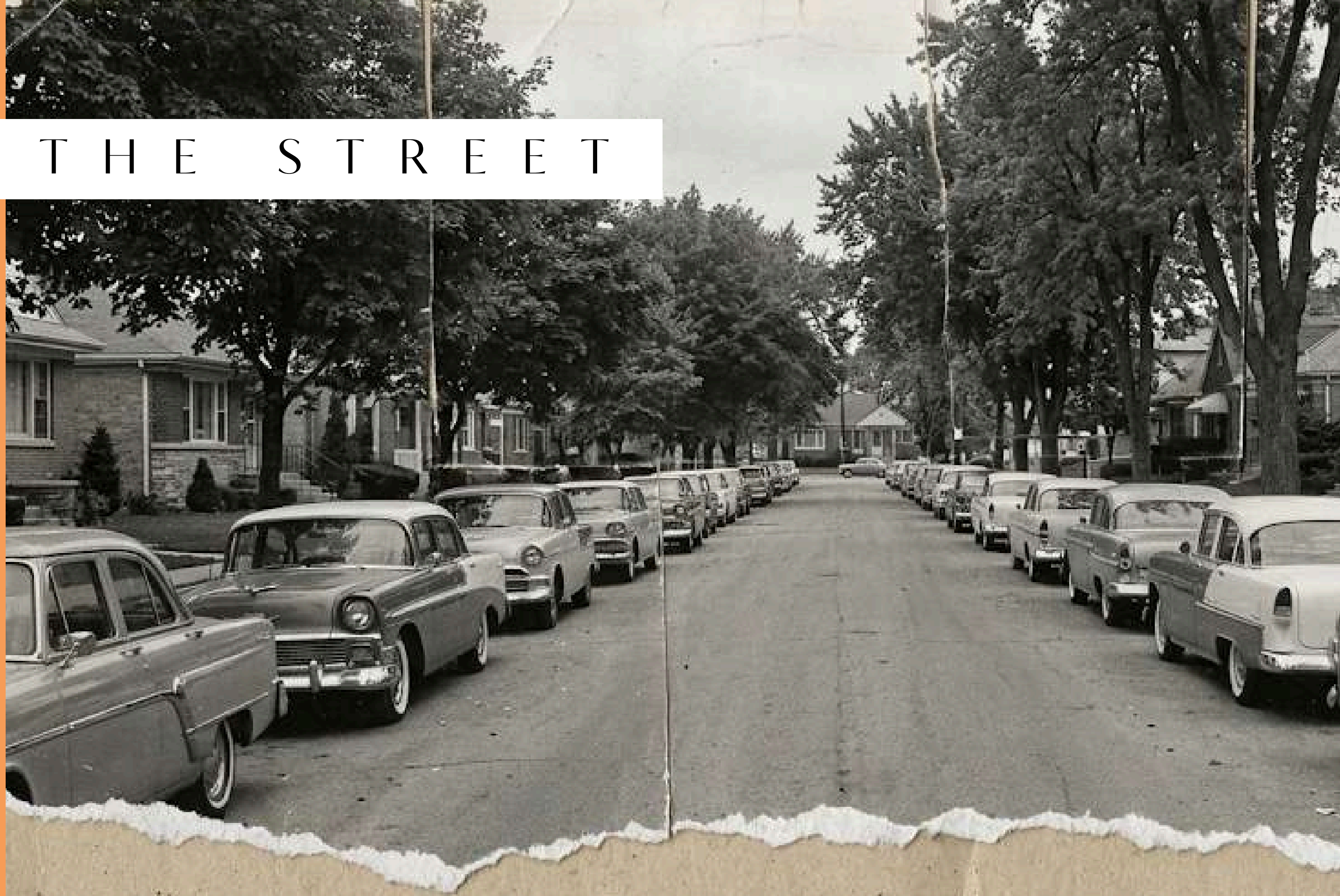
Stakeholders - who lives with the system

A F E W P E O P L E , M O S T O F T H E S T R E E T

Average car occupancy for urban trips across Europe runs roughly 1.2 to 1.9 people per vehicle, and that's while moving - a parked car carries nobody. A standard residential street holds dozens of parking spaces, each occupying roughly the footprint of a small room, to represent, at any given moment, a small fraction of the people who in practice live on or pass through that street. The space allocated and the population served are two very different numbers, and the gap between them is what this system's curb reallocation is in practice spending.

The comparison that makes this concrete rather than abstract: a single car parking space holds one vehicle. The same footprint holds several bicycles or one loading bay that serves an entire street's deliveries on a schedule rather than permanently. Worth being precise about what this argument is and isn't: it's not a claim that cars should disappear - it's that the specific space this project reclaims for scheduled loading was never serving as many people as its size implies, freight vehicle or private car alike.

The direct freight version, not borrowed from the general case: delivery vehicles by now spend up to 40% of route time stationary, frequently double-parked, precisely the same visibility and safety problem that this parking argument makes about private cars, just larger, more frequent, and less predictable. What residents give up: some curb space converted to scheduled loading rather than open or informal use - a real trade-off, named plainly rather than hidden.

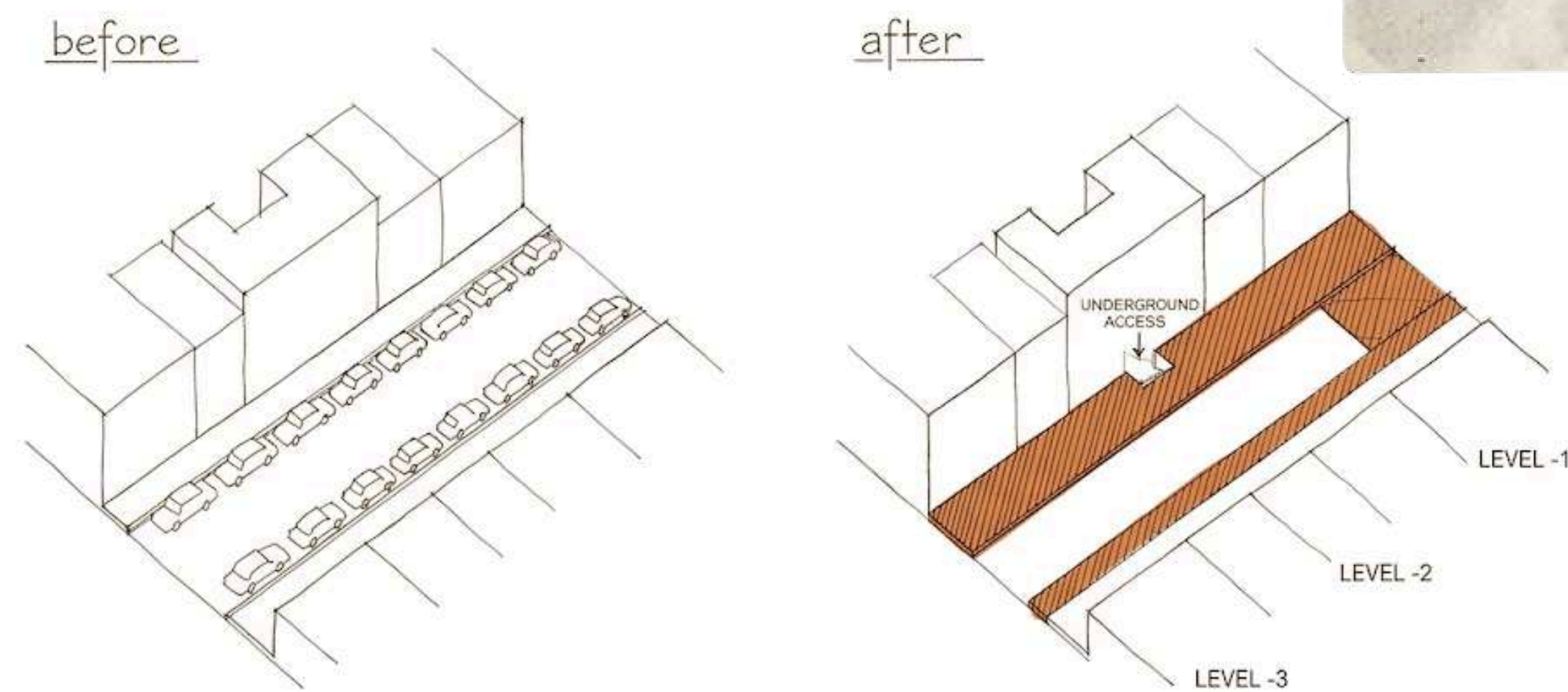


Stakeholders - who has to say yes

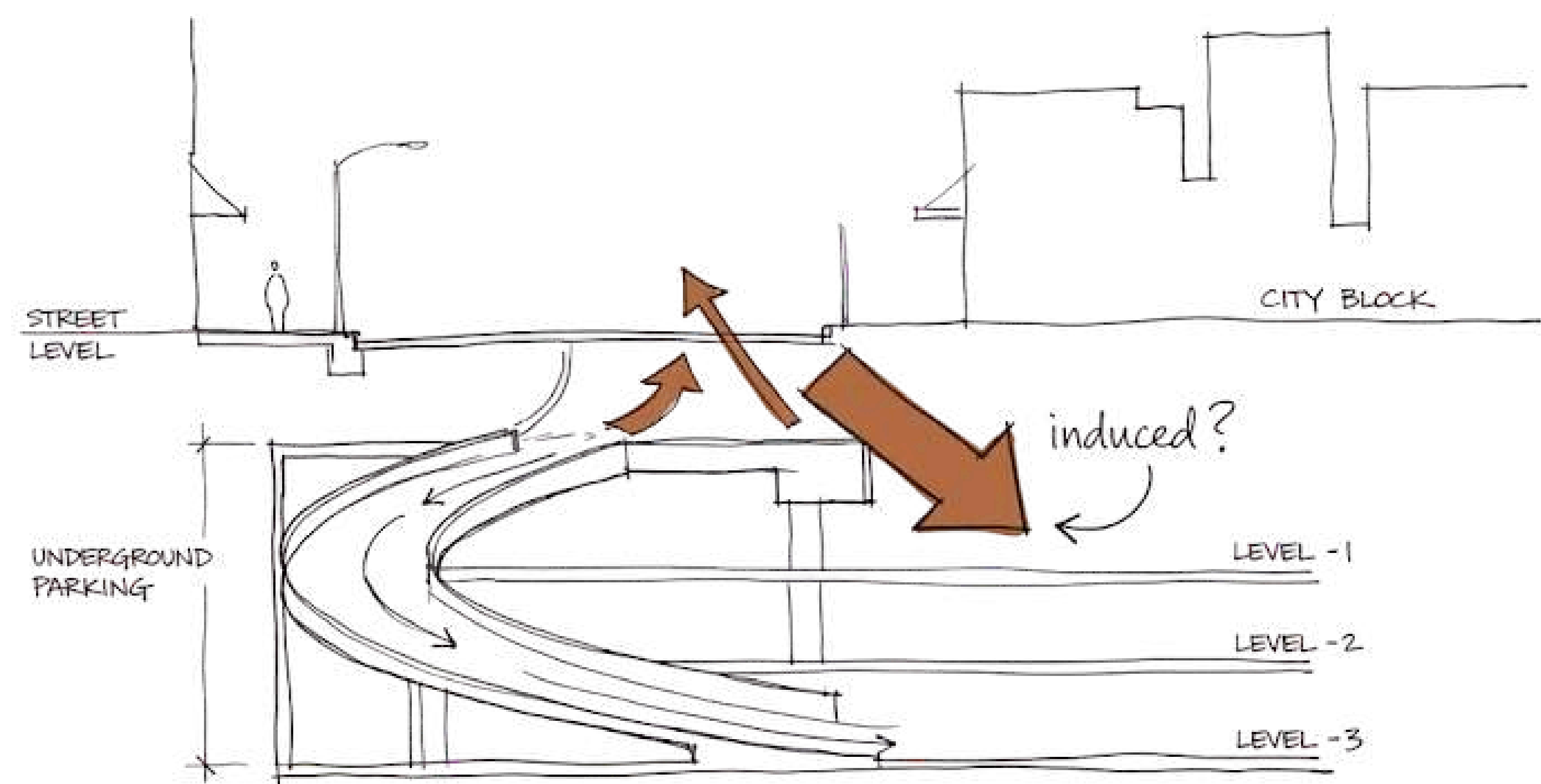
NOT A NEW KIND OF ASK, A
CONTINUATION OF ONE BY NOW
MADE

Amsterdam has by now reallocated valuable surface space once-moving car storage underground to free the street for other uses. This system's hub-siting logic extends that same precedent rather than introducing a new category of decision the city hasn't faced before. That matters for buy-in specifically: the harder political fight, precedent-setting reallocation of public space, has by now happened once and been absorbed.

It's worth naming the counterargument directly, since it's the harder and more honest version of this claim, not the safer one: building generous, well-funded infrastructure for a form of movement can itself induce more of that movement-the same critique made of the underground garage that reduced surface parking but reportedly increased the very driving it was meant to accommodate. This project isn't exempt from that logic. A well-run, convenient hub network could plausibly increase total delivery volume rather than only redistributing it more cleanly. The honest response is narrower than a denial: the impact KPI measures ZEZ vehicle entries per 1,000 parcels, not total parcel volume, so the system's own success metric holds even if volume grows. Whether total urban freight volume should itself be constrained is a policy question this project doesn't attempt to answer.

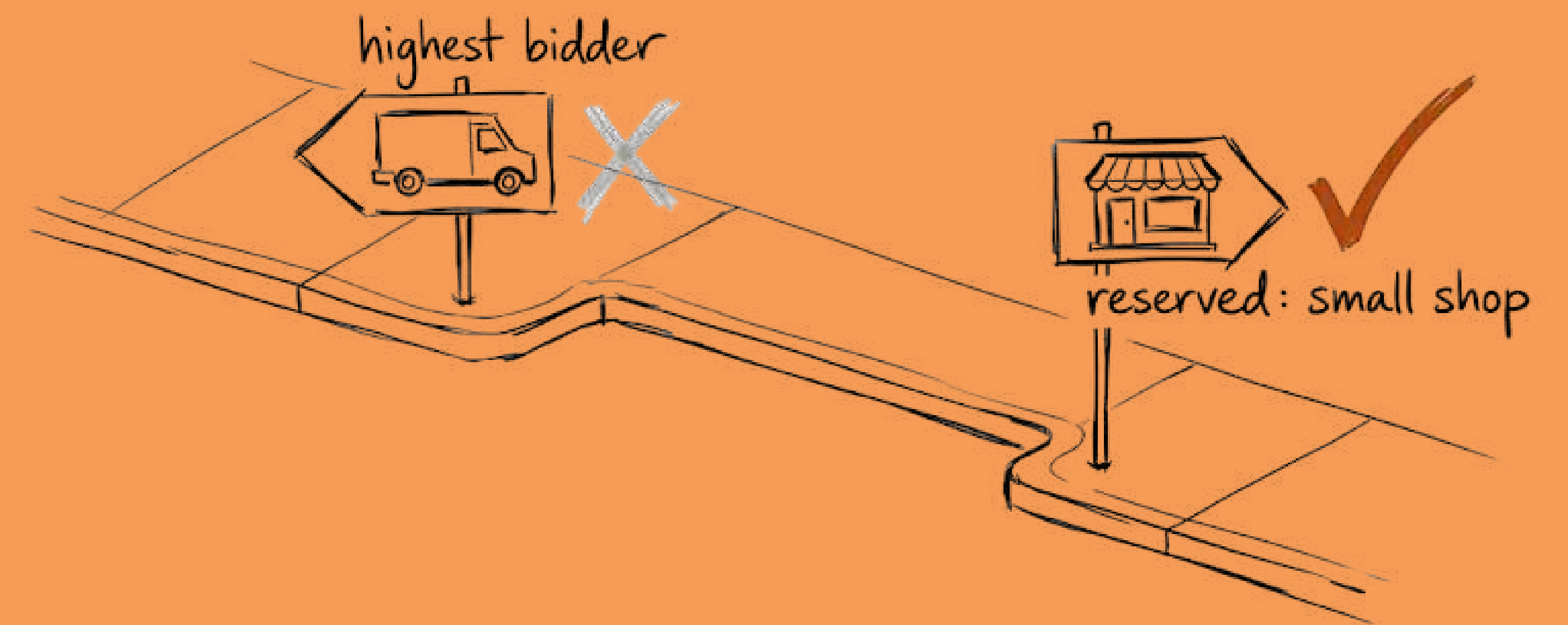


One more precedent worth citing directly, since it reframes the whole ask in terms a city budget office understands: infrastructure built for the mode being displaced is often the more expensive option, not the cheaper one - a pattern by now visible in how much less a modest reallocation of existing space costs against major new construction, the same relationship this project's siting logic depends on throughout: reuse over building new.



Trade-offs - what the system gives up

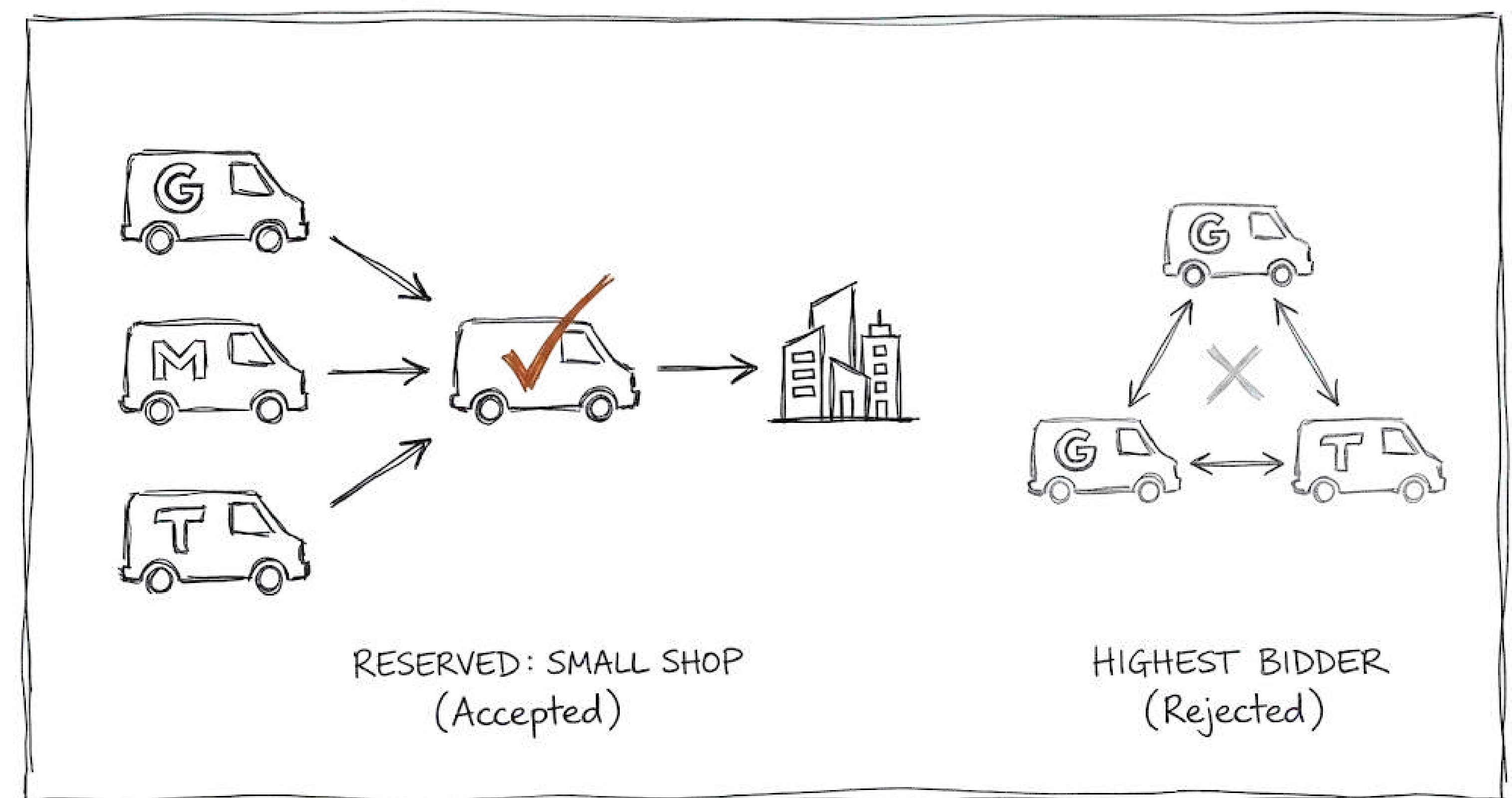
THREE THINGS THIS
SYSTEM COULD NOT
MAXIMISE AT ONCE



Small-shop access against pricing efficiency. A curb allocated purely to whoever values it most goes to whoever can pay most, which is the large chain every time. Reserved small-shop slots by design allocate against willingness to pay. Chosen: equity. The reason is structural, not moral - a system that invisibly hands the zone to large operators reproduces the exact capital gap ZEZ enforcement by now created, and the project's own value proposition collapses if its mechanism accelerates the thing it exists to counter.

Neutral operator against carrier control. Handing final delivery to a third party costs carriers the branded face of their own delivery and direct visibility into their last leg - a documented, real objection, not a hypothetical one. Chosen: neutral operator. It's the only arrangement with a working track record for the competitor-data problem: Gnewt Cargo and UCC Amsterdam both run this way, and no shared-hub model requiring carriers to share operational data with each other has survived.

Single time-shared channel against dual capacity. One channel means inbound and outbound flows can't run simultaneously, which becomes the bottleneck at peak. Chosen: single, with a second channel gated on volume. The expensive part of any physical link is the excavation, not the mechanism riding through it - building capacity for demand that hasn't been demonstrated is precisely the bet Cargo Sous Terrain lost.



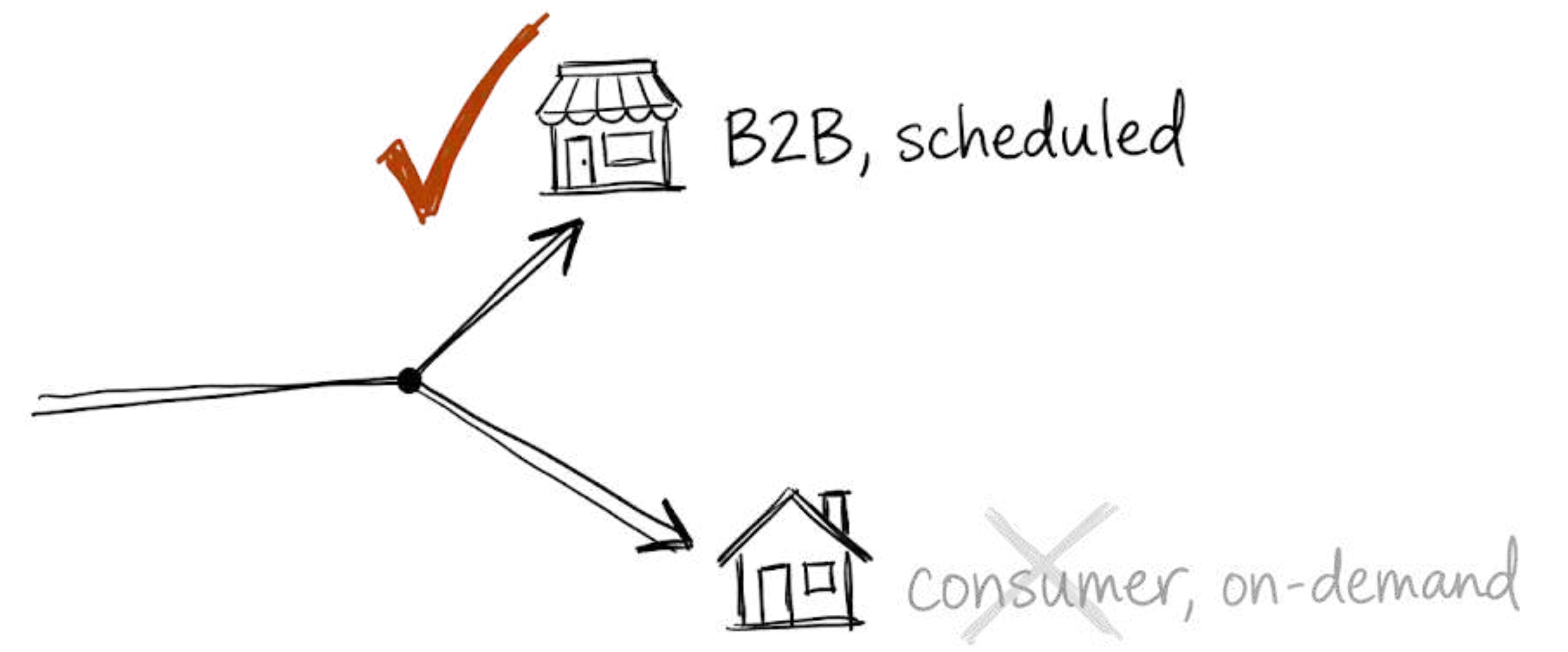
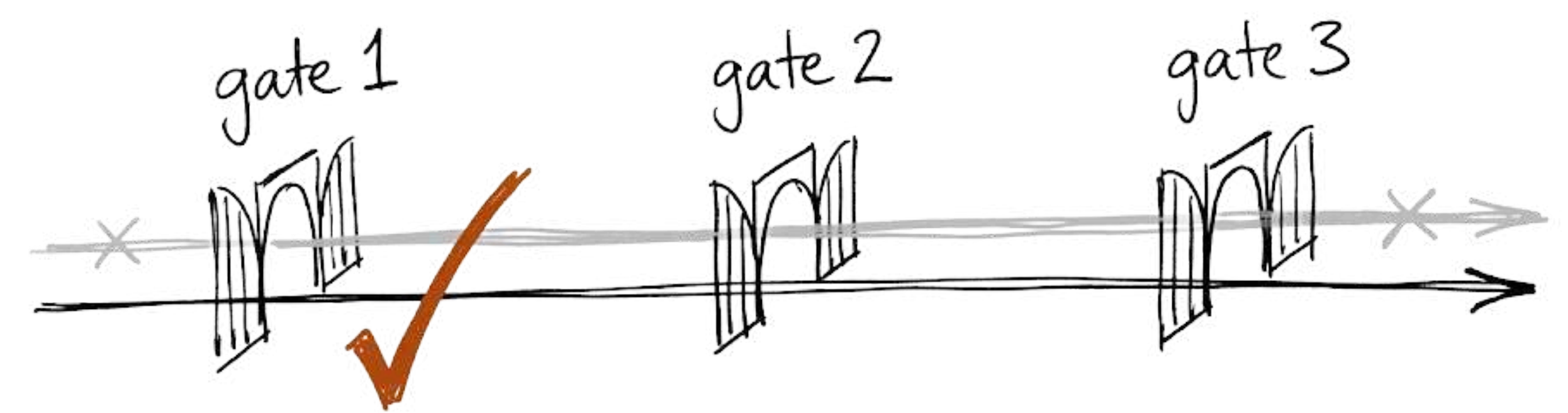
Trade-offs - what this project declines to do

THREE MORE, INCLUDING
ONE THIS PROJECT
CANNOT RESOLVE

B2B only, excluding consumer parcels. Consumer volume is the larger and faster-growing market, and excluding it caps the system's reach considerably. Chosen: B2B. Business deliveries run on standing contracts and predictable schedules, which is what makes slot booking work at all; consumer parcels are an on-demand flow problem that would break the scheduling mechanism this system depends on. Including both would mean designing neither well.

Phase-gated caution against speed of impact. Every gate delays the point at which the system delivers measurable benefit, and a multi-year rollout can fairly be read as slow. Chosen: gates. The alternative is the documented failure pattern - 13 of 20 closed European consolidation centres failed for financial reasons, most often because volume assumptions were committed to before being tested.

And the one that stays open: does making consolidation cheap and convenient increase total delivery volume? The same logic that says convenience determines carrier behaviour also says convenient infrastructure induces demand - the reason generous parking generates more driving. This project has no mechanism that prevents it, and claiming otherwise would be dishonest. What can be said is narrower and true: the impact KPI measures vehicle entries per 1,000 parcels, not total parcel volume, so the system's own success metric stays valid even if volume grows. Whether total urban freight volume should be constrained is a policy question this project by design does not attempt to answer.



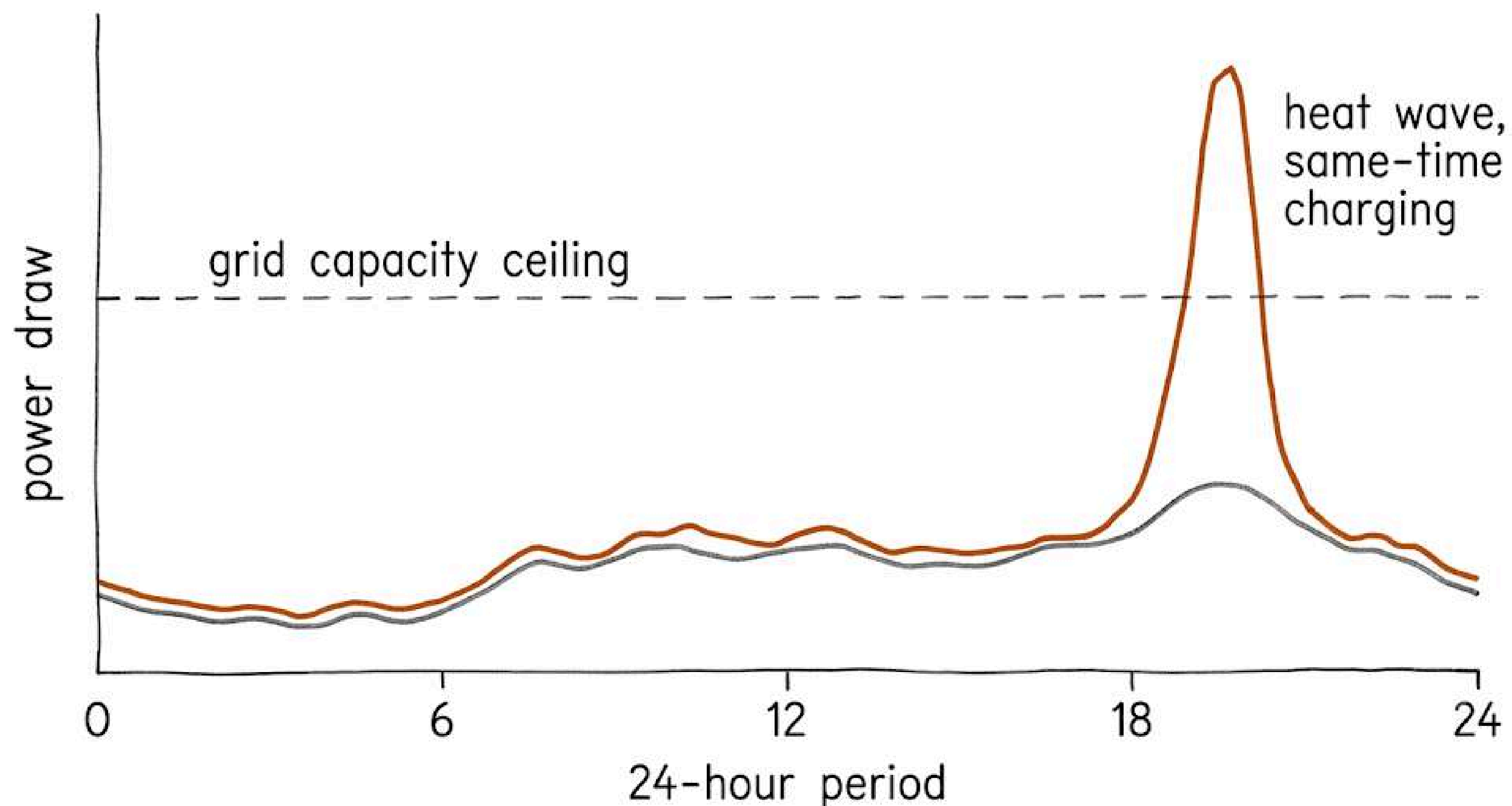
Scenario 1 - Heat Wave

WHAT HAPPENS WHEN EVERYONE PLUGS IN ON THE SAME SCHEDULE



Grid capacity isn't sized for every connected vehicle charging at once - it's sized on a diversity factor, the assumption that demand spreads out because ordinary households and fleets don't all draw power on the same schedule. A heat wave over 40°C breaks that assumption in two directions simultaneously: cooling demand across the wider city grid spikes at precisely the same time the hub's own fleet needs its heaviest overnight charging window, and heat itself degrades battery charging efficiency, meaning the fleet draws more power to do the same work, not less.

This lands directly on the constraint by now established as physical, not adjustable: capacity, fixed at build time, with no operational fix available once a site is chosen. A booking system can reschedule when vehicles charge. It cannot manufacture power that doesn't exist at the substation. And the honest complication underneath both scenarios in this section: transformer and cable procurement by now runs two to three years for cables and up to four for large transformers, lead times roughly doubled since 2021 - "just upgrade the grid connection" isn't an available fix on short notice in this scenario or the last one.



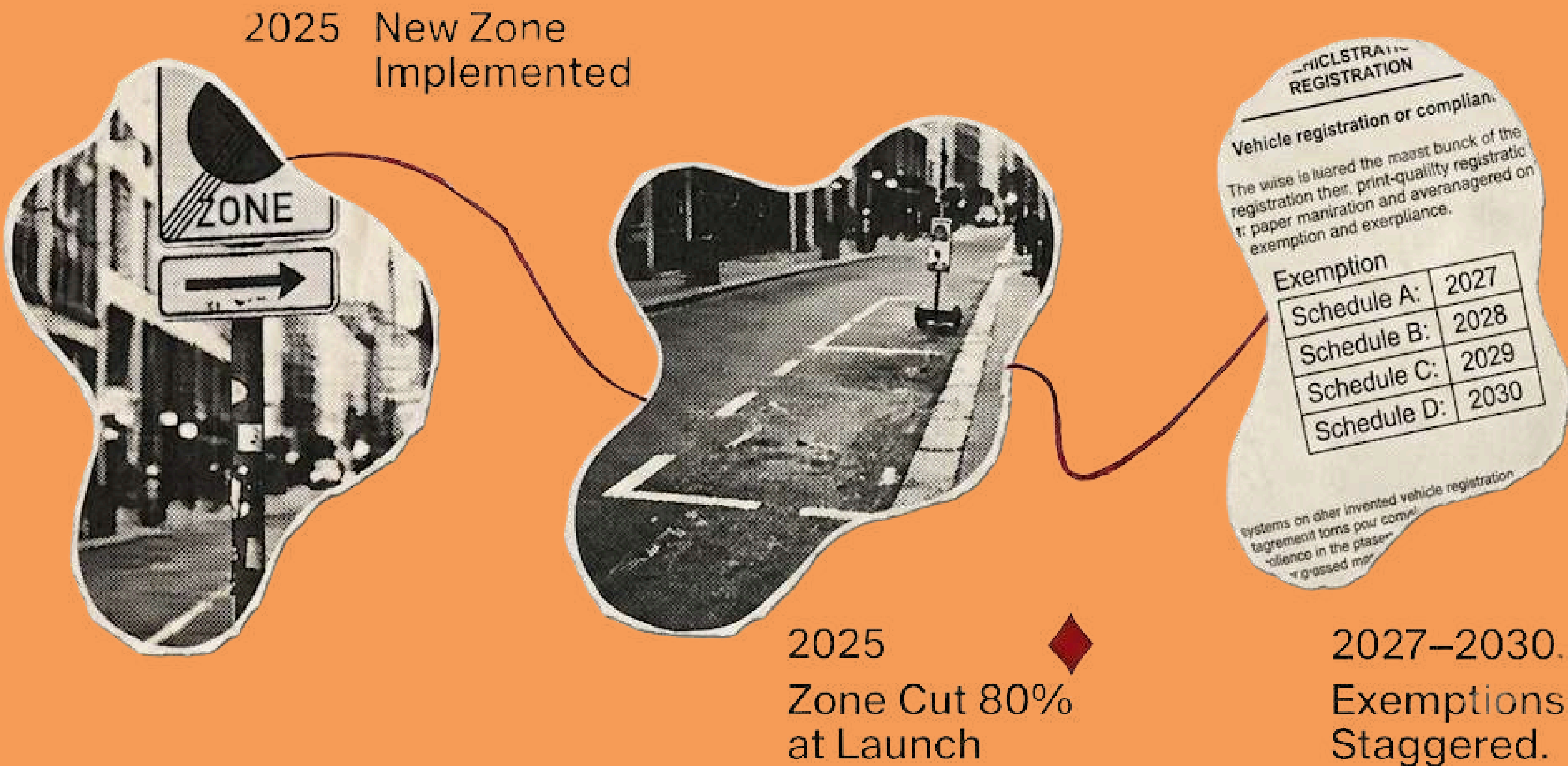
What holds regardless is that the system was never designed assuming unlimited capacity. Tiered, priced access spreading charging across off-peak hours - the allocation half of the electricity split established earlier - is precisely the mechanism built for precisely this kind of demand spike, not a new fix invented for the occasion.

Scenario 2 - Regulatory Softening

WHAT HAPPENS IF
THE MANDATE
WEAKENS INSTEAD
OF HOLDING FIRM

This isn't hypothetical - it's by now underway. Amsterdam's own zone was cut by roughly 80% at the last minute. Apeldoorn and other cities pushed implementation to 2030. The Dutch Secretary of State has declined to rule out reversing the zones entirely. Businesses were granted a year's grace period on penalties as a political compromise, layered on top of staggered vehicle exemptions by now built into the rollout-Euro 5 vans admitted until January 2027, Euro 6 until 2028, and Euro VI trucks until 2030.

That's not a footnote to the regulation. It's the actual shape of the demand curve this system depends on. Every exemption expiry date is a point where compliance-driven volume either arrives or doesn't, and the pattern so far is retreat, not acceleration.



Here's why this is the scenario worth sitting with rather than deflecting: it's the one that tests whether the system's value depends on compulsion or stands on its own. A single-purpose compliance facility - built only to catch trucks that legally can't enter otherwise - dies the moment that compulsion weakens, the same failure mode behind most closed European UCCs. This system was built with more than one reason to exist: reused space with ordinary logistics value regardless of enforcement, a neutral operator solving a real coordination problem independent of any mandate, an equity mechanism serving small shops whether or not ZE₃₀ holds. Softening enforcement doesn't erase those reasons. It removes one of several, not the only one.

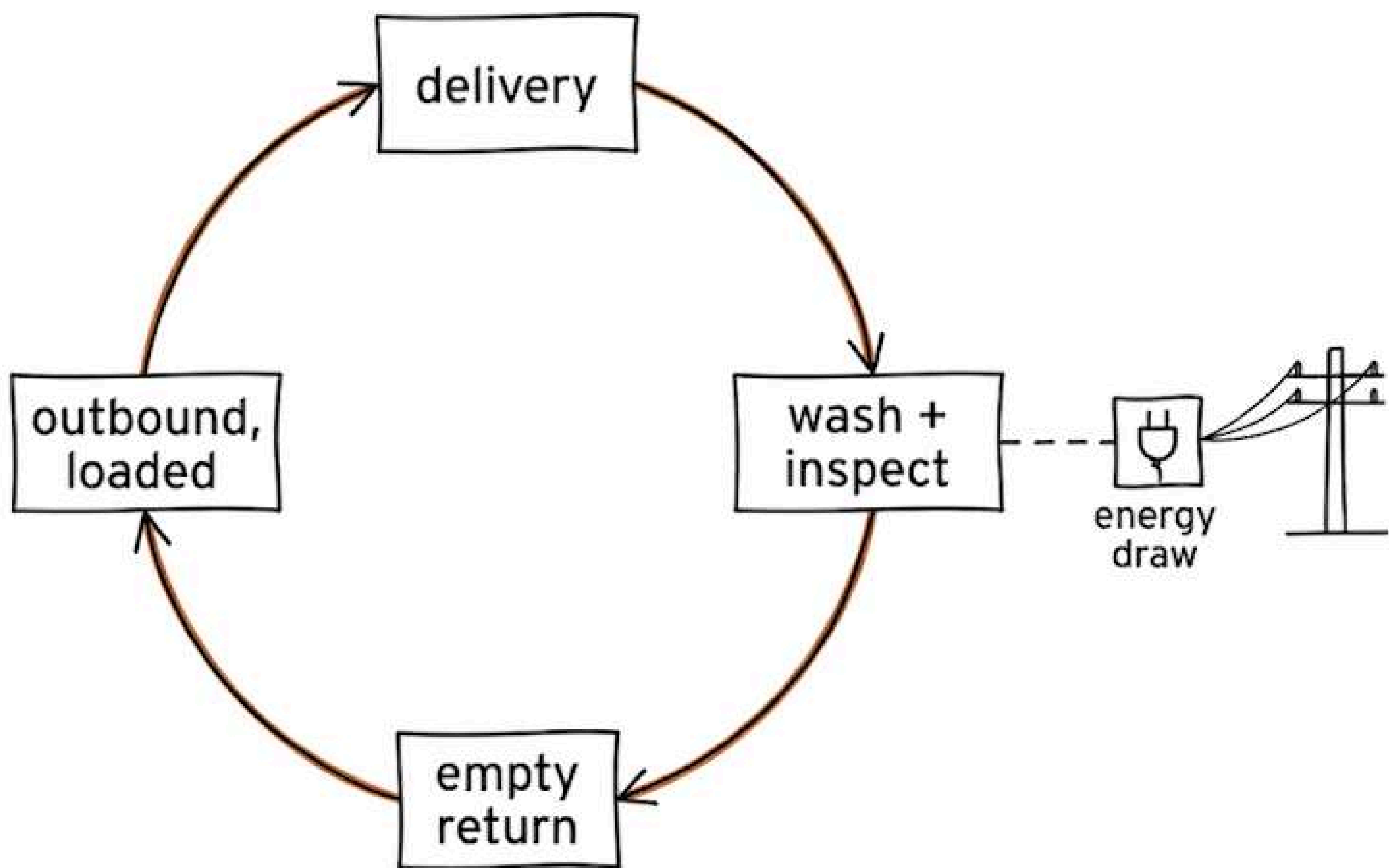
Scenario 3 - The Reuse Mandate Bites

WHAT HAPPENS WHEN
PACKAGING STOPS
BEING WASTE AND
BECOMES AN ASSET
THAT HAS TO COME
BACK



The Packaging and Packaging Waste Regulation applies from August 12, 2026 - weeks after this project's own deadline - and by 2030 at least 40% of transport, industrial, and e-commerce packaging must be reusable, rising toward 70% by 2040. That's not a footnote about sustainability. It converts packaging from something a delivery vehicle drops off and forgets into a circulating asset the system is now legally obligated to collect, track, and return.

Every empty crate or pallet coming back into the hub needs washing, inspection, and buffering before it can be matched to the next outbound load. That's a new physical process, not a paperwork requirement - and it's a genuinely energy-hungry one, which pulls this scenario directly back into the last one's territory: a washing facility draws its own load, on the same grid, under the same capacity ceiling by now established as fixed at build time. Two scenarios that look unrelated on the surface - heat and packaging - converge on the identical constraint underneath.



What this tests specifically: whether the reverse-logistics half of this system, present from the very first ideation board but never load-bearing until now, can absorb a real regulatory obligation rather than staying a nice-to-have. The bidirectional connector - the counterweighted loop by now carrying empty containers back on every trip - was built for precisely this traffic. What wasn't built yet, and what this scenario forces into the open, is the washing and tracking step sitting between the connector and the outbound load.

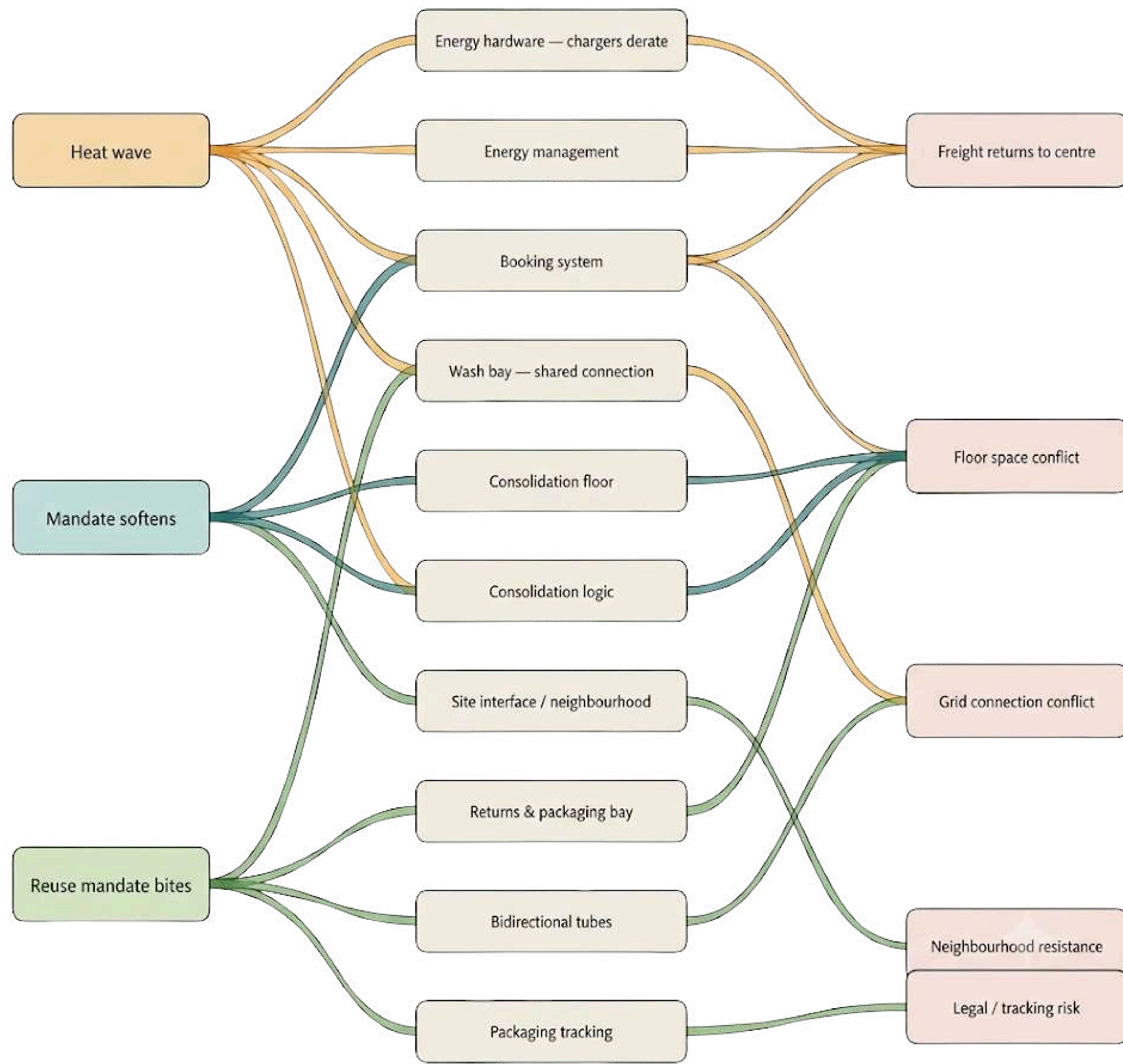
Resilience - how this was actually tested

YOU DON'T FIND
OUT WHAT A
SYSTEM IS MADE
OF UNTIL YOU
TRY TO BREAK IT

Every claim so far in this project has been about what the system does when things go right. This section runs the opposite question: for each of three genuinely disruptive futures, what specifically fails, and does the system have an answer that was already there, or does it get caught with nothing?

The method is simple enough to state in one sentence: for every scenario, walk through the system piece by piece, and for each piece ask three things - what breaks first, what does that break cause downstream, and would anyone actually notice before it became a problem. No probability scores, no invented likelihood of a heatwave or a policy reversal happening in a given year - pretending to know that with precision would be dishonest, so the analysis stays qualitative on purpose rather than dressing up a guess as a number.

Sixteen of these walk-throughs were run, split unevenly across three scenarios - six, five, five - because forcing every scenario to produce the same number of findings would mean padding weak ones and cutting strong ones just to match a template. Two patterns emerged that turned out to matter more than any individual failure: several failures from completely different causes converge on the same downstream effect, and - more importantly - the three scenarios aren't independent of each other. A fix built to survive one can quietly make another worse.



Resilience - what actually breaks, and where it lands

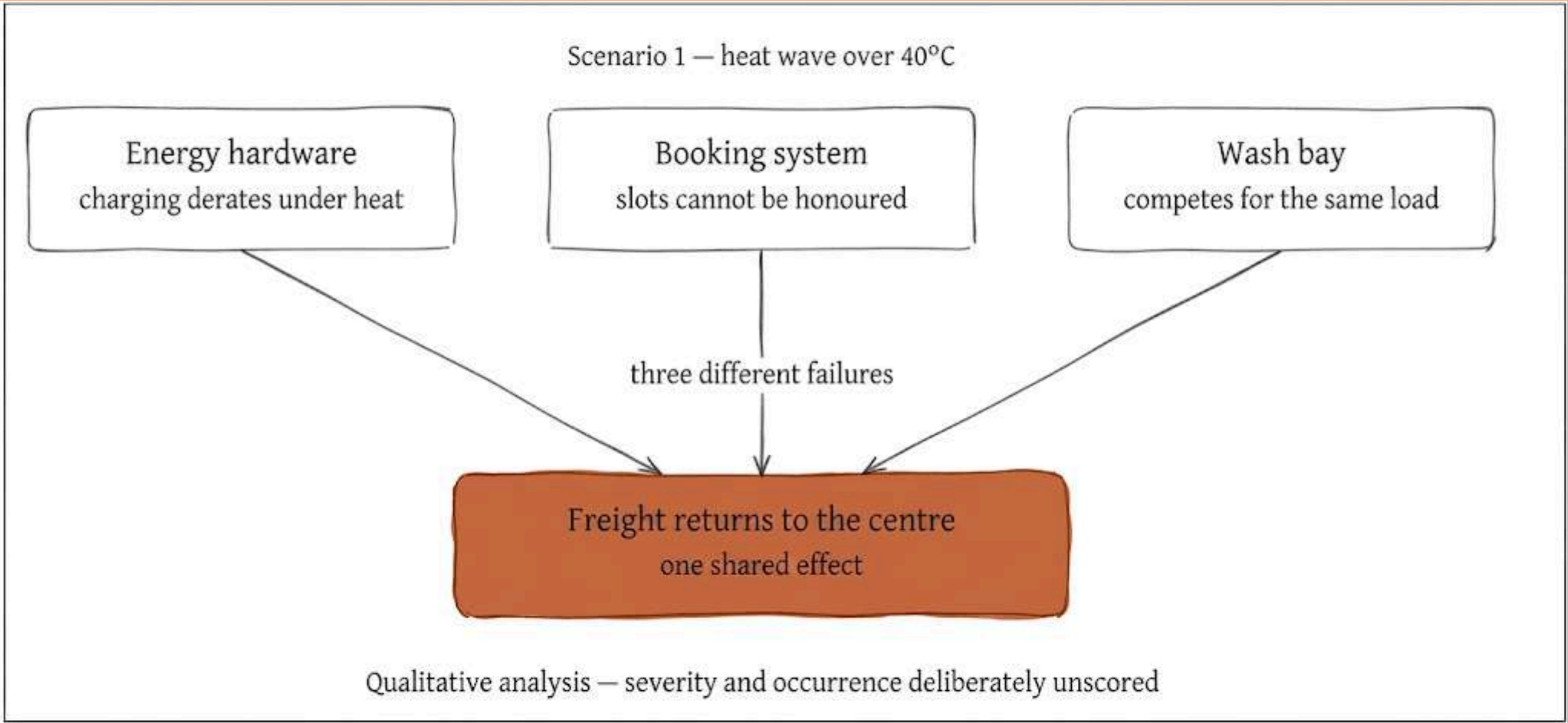
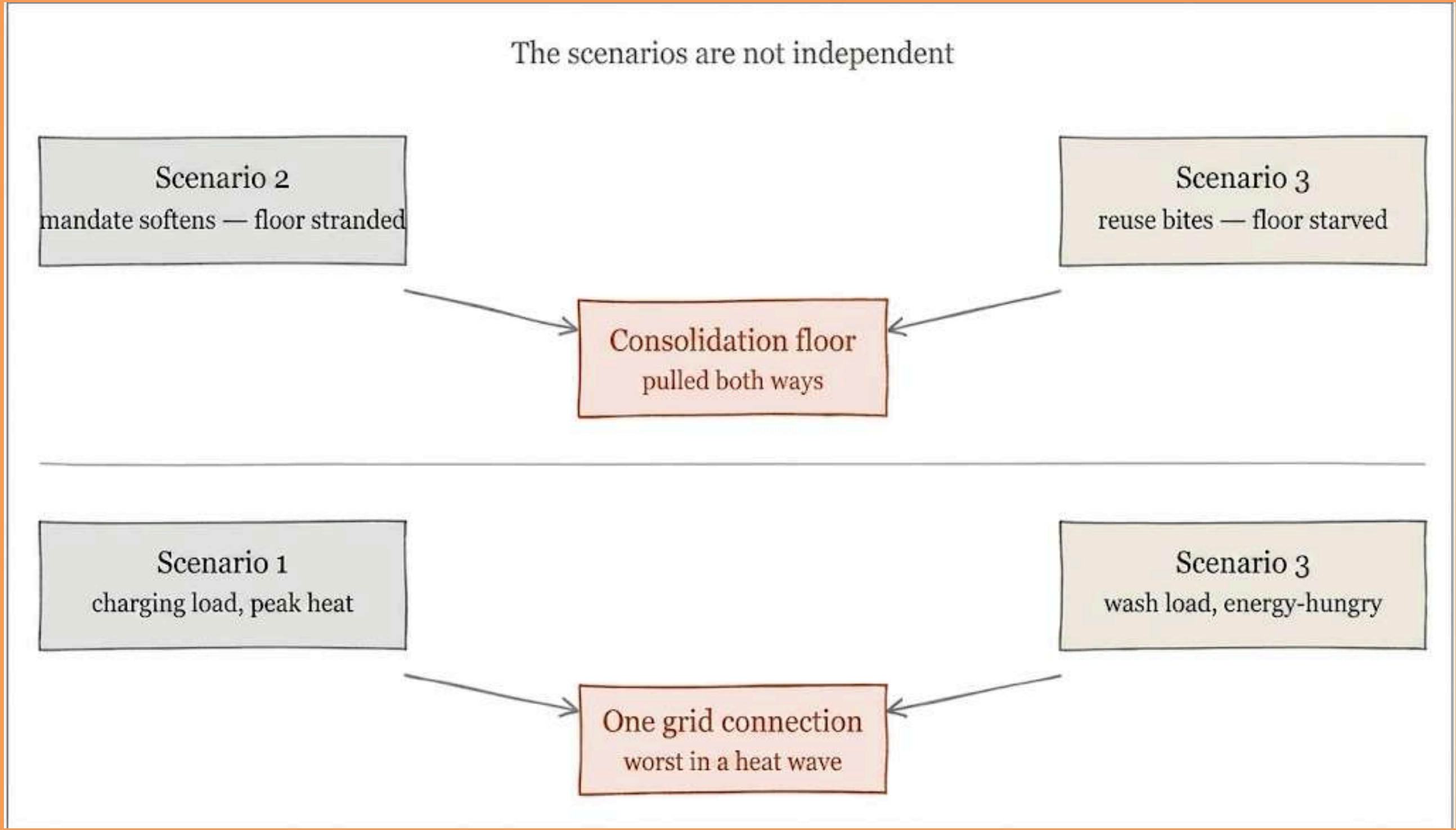
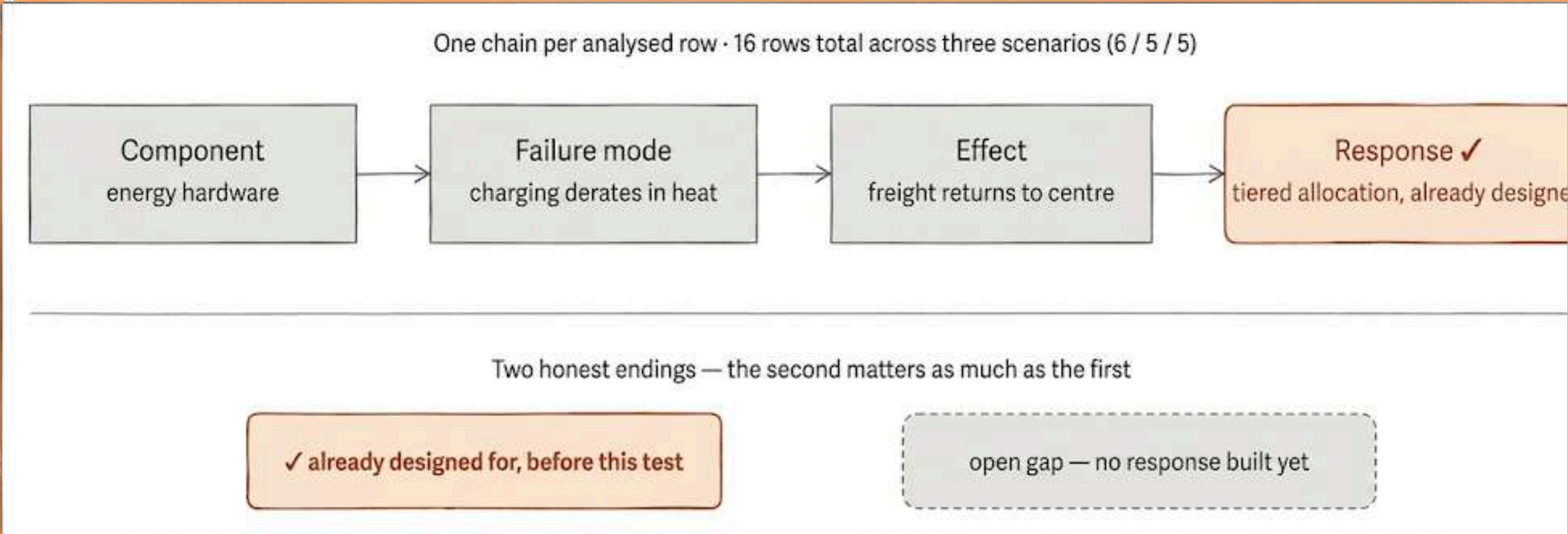
THREE SCENARIOS,
TEN COMPONENTS,
AND TWO FINDINGS A
SINGLE-SCENARIO
TEST WOULD NEVER
CATCH

Run heat, regulatory softening, and the reuse mandate against all ten of the system's components, and two things emerge that no individual scenario reveals on its own.

Convergence. Under sustained heat, four separate components fail for four separate reasons - chargers derate, energy management runs out of headroom, booked slots go unmet, the wash bay competes for the same connection - and every one of those failures lands on the identical effect: freight stops clearing the hub and returns to the city centre. That's not four weak points. It's one real vulnerability with four different triggers, which changes where the actual fix needs to sit.

Collision. The three scenarios pull against each other, not alongside each other. Regulatory softening strands consolidation floor space - less freight than the hub was sized for. The reuse mandate does the opposite on the same floor - packaging returns competing for room to wash and buffer. Same physical resource, opposite direction of failure. And separately, the reuse mandate's wash load and the heat wave's charging load compete for one shared grid connection, at its worst exactly when heat is already stressing that connection alone. A system tested one scenario at a time would never surface either of these - they only exist because the scenarios were run against the same ten components rather than in isolation.

What holds, and why it holds: tiered, priced charging access - built for ordinary demand variation, not invented for this test - turns out to answer the heat-wave spike too. That's the difference between a system that survives because of something purpose-built and one that survives because a mechanism built for something else happened to be enough.



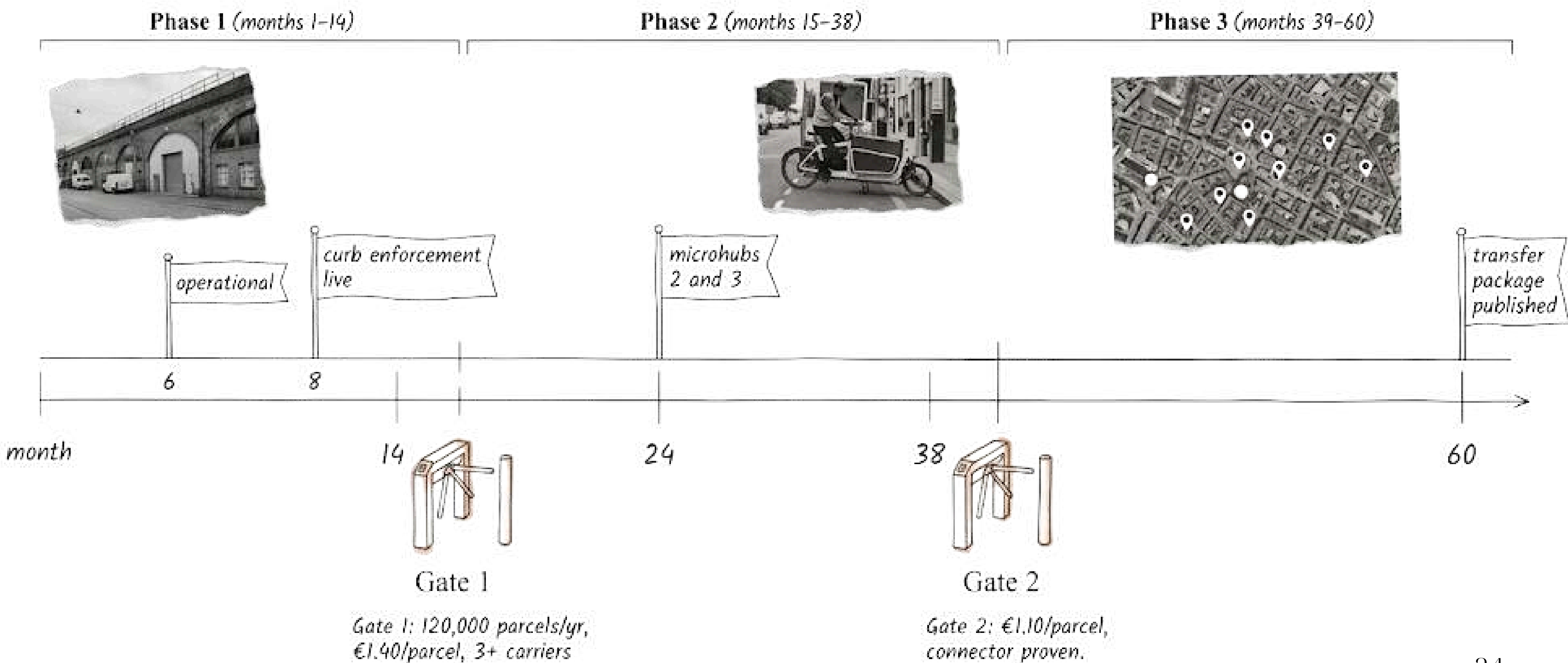
T E N Y E A R S , T H R E E P H A S E S , G A T E D B Y E V I D E N C E
I N S T E A D O F A C A L E N D A R

Every phase boundary in this roadmap is a decision point with a stated threshold, not a date picked because it looked reasonable on a timeline. That discipline exists for a specific, documented reason: of 82 European urban consolidation centres mapped in a recent state-of-practice review, 20 had closed, and 13 of those closures were driven by financial reasons - utilisation below the business-case assumption, most often, because volume was committed to before it was tested. Gates exist to catch exactly that failure before money follows it.

Phase 1 - Prove it works, Months 1–14. Site secured with grid capacity confirmed before anything is leased, since capacity is fixed at build time with no fix available afterward. Anchor carriers signed before construction begins, not after - the Gnewt Cargo pattern, demand proven ahead of supply. Operational by Month 6, curb enforcement integrated by Month 8. Gate 1, Month 14: throughput at or above 120,000 parcels a year, cost per parcel at or below €1.40, at least three carriers still active. Miss it, and the response is named in advance - reprice the fee, adjust the carrier mix, or hold at pilot scale rather than proceed on hope.

Phase 2 - Extend and test the bet, Months 15–38. The connector gets its first real engineering costing here, immediately post-gate - this is deliberately the first point any money is committed to it. Microhubs two and three go live at Month 24, testing whether the cost curve behaves as modelled. Gate 2, Month 38: cost per parcel at or below €1.10, the connector showing a measurable advantage over the van leg it replaces. If it underperforms, the hub network continues without it - that layer was designed to be able to fail without taking the rest down.

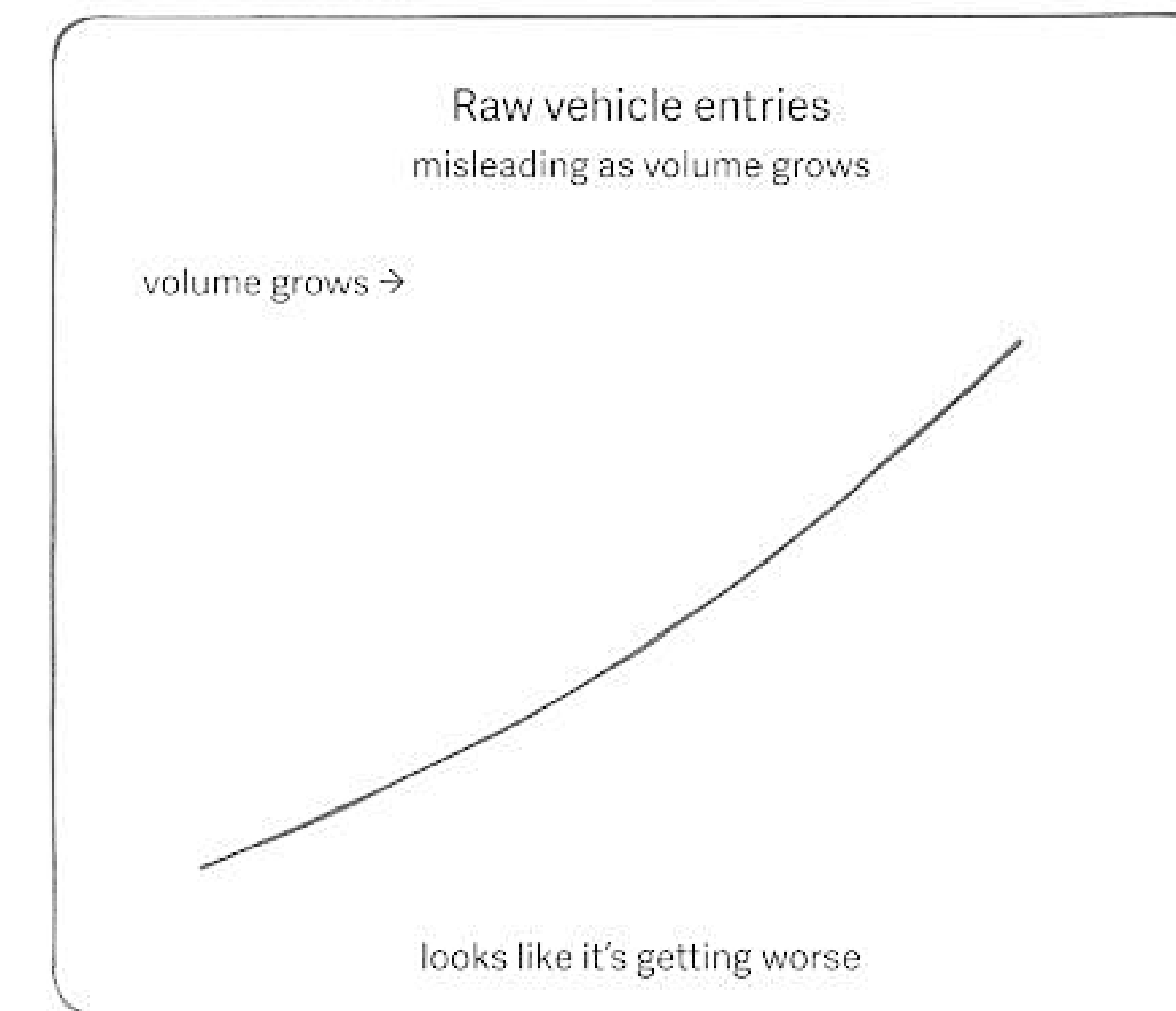
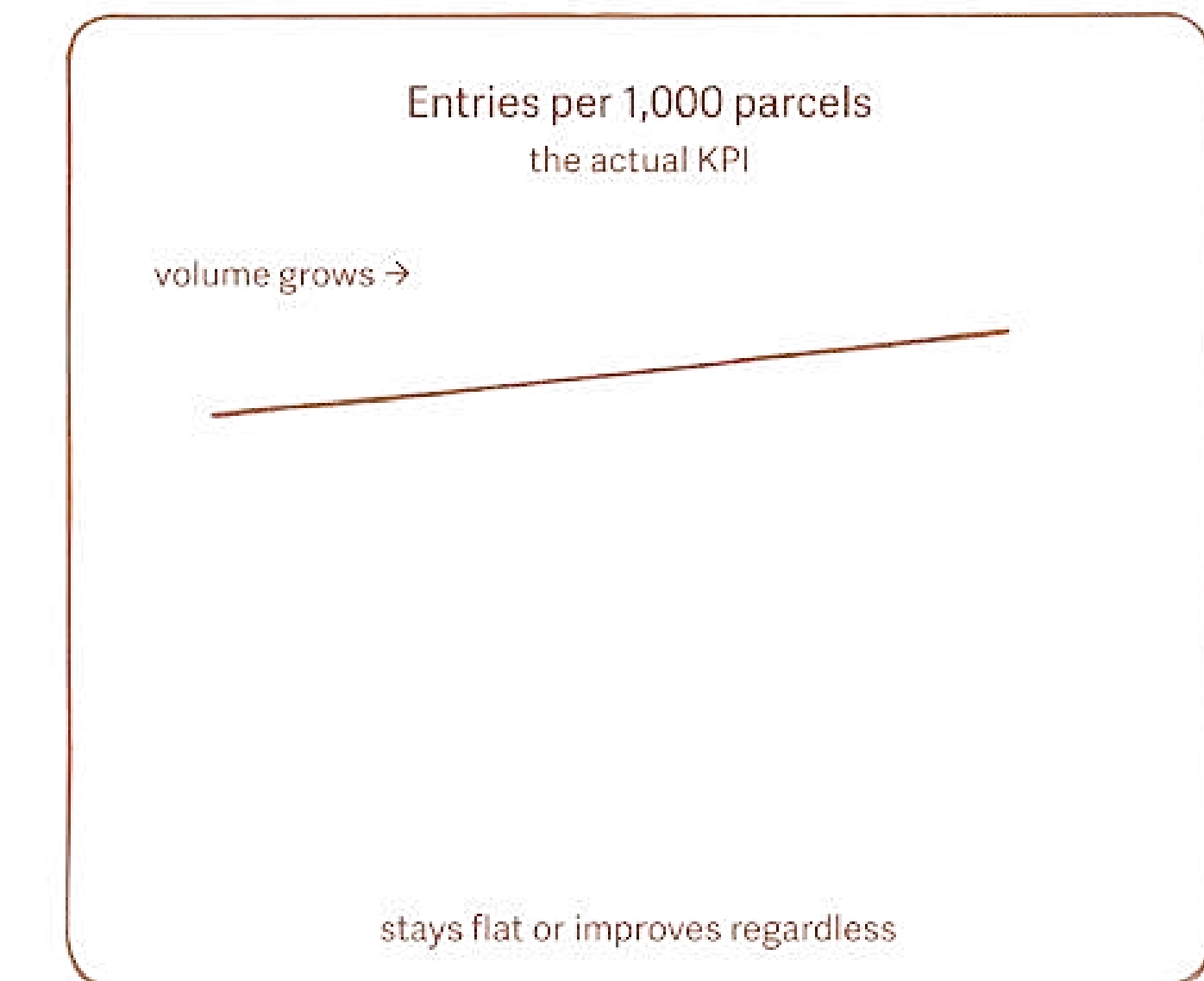
Phase 3 - Replicate, Months 39–60. A second boundary hub, nine microhubs city-wide, and a documented transfer package for the other 28 Dutch municipalities running the identical regulation by 2030.



Impact - the metric

ONE NUMBER,
CHOSEN BECAUSE
THE OBVIOUS ONE
WOULD FLATTER
THE WRONG THING

The obvious **KPI** for this project is CO₂ reduction. It was deliberately not chosen. ZEZ regulation already mandates electric vehicles inside the zone, so most of the emissions reduction a chart would show is attributable to the regulation itself, not to anything this system specifically contributes. A CO₂ number would look impressive and measure someone else's policy.



The actual KPI: delivery vehicle entries into the zero-emission zone, per 1,000 parcels delivered. This isolates the one effect that's genuinely the system's own - consolidation reducing how many individual vehicles are needed to move a given volume of freight, independent of what powers them. It's also the metric that survives the induced-demand tension raised earlier in this project: because it's a ratio, not a raw count, it holds even if a convenient, well-run hub increases total delivery volume. A rising parcel count doesn't quietly flatter this number the way it would a simple vehicle-count or emissions figure.

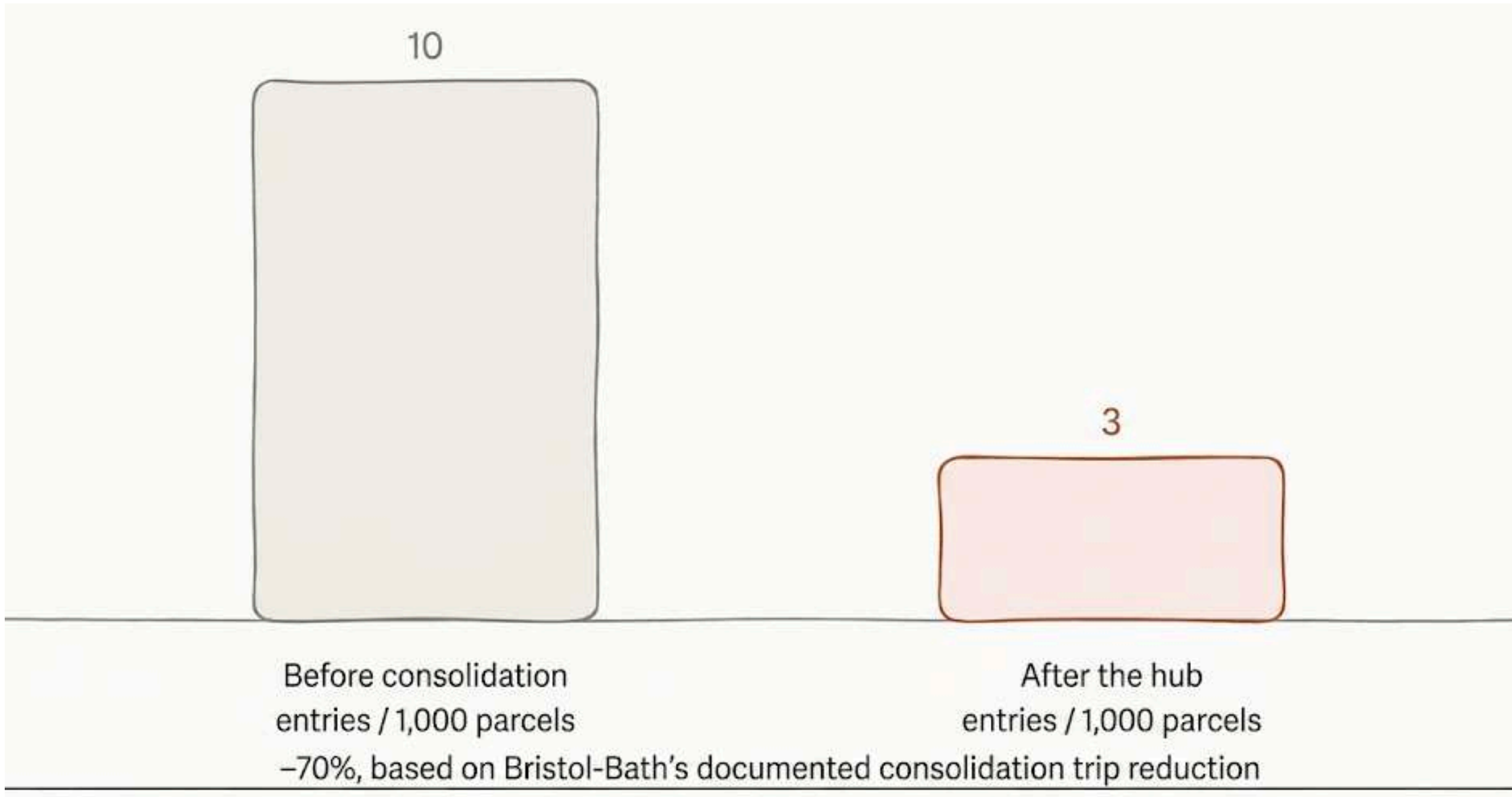
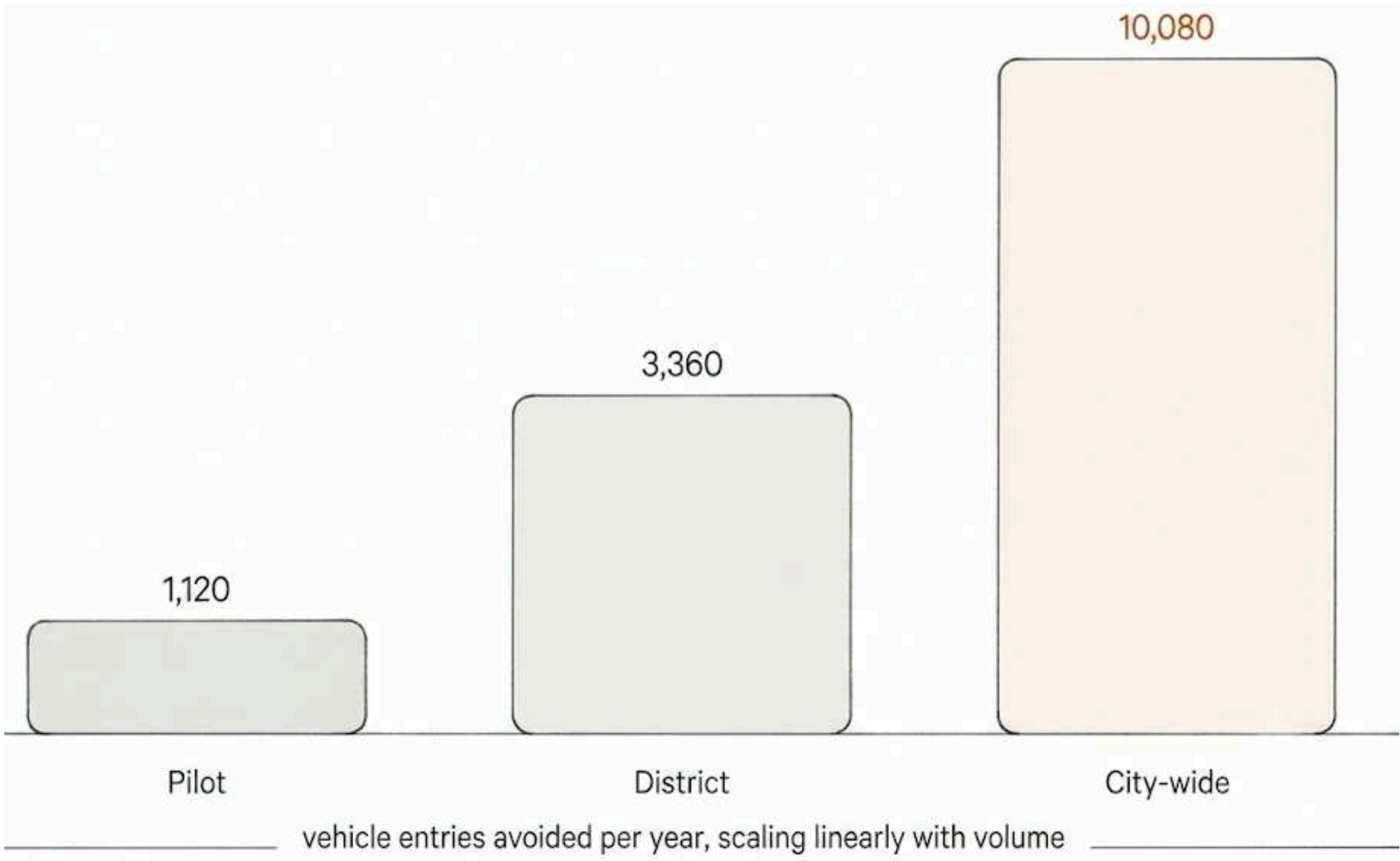
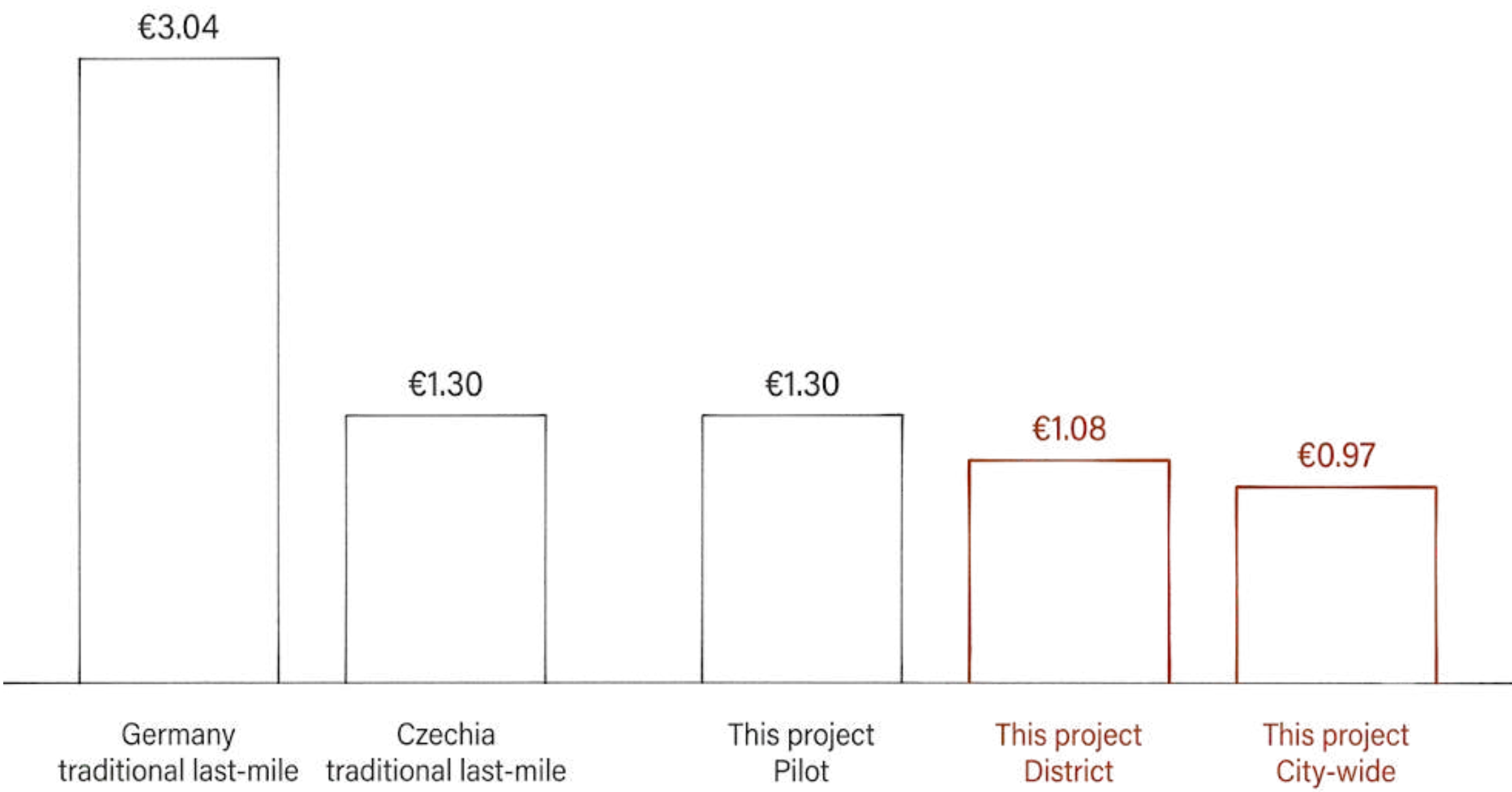
Measurement isn't hypothetical. ANPR enforcement data already collected at zone boundaries provides the real baseline entry count, no new sensor infrastructure required. The hub's own consolidation-floor throughput, modelled against dock capacity, produces the projected post-hub state. Two existing data sources, not a survey built from nothing.



Impact - the number
FROM ROUGHLY 10
ENTRIES TO
ROUGHLY 3, PER
1,000 PARCELS



The target: a 70% reduction, benchmarked against the Bristol-Bath Freight Consolidation Centre - the closest directly comparable case with a real, documented trip-reduction figure, where 190 of 240 retail outlets used the centre and vehicle trips fell by approximately 70% for goods flowing through it. Applied to this project's own Phase 1 volume, already established at 160,000 parcels a year, that reduction is worth roughly 1,120 avoided vehicle entries annually at pilot scale alone - before Phase 2 or Phase 3 multiply it further.



Two things worth stating plainly rather than smoothing over. First, the underlying per-van parcel assumption behind the baseline figure is exactly that - an assumption, not a sourced number, and it's flagged as such rather than dressed up as more certain than it is. Second, Bristol-Bath is a proxy from a different city; Amsterdam's own baseline entry rate is still a real, open research need, not yet confirmed. The logic of the KPI is sound regardless of that gap; the specific figures aren't being presented as more finished than they are.

Traditional last-mile delivery costs €3.04 per parcel in a high-wage EU country like Germany, and €1.30 in a low-wage one like Czechia - the gap is almost entirely labour cost, and the Netherlands sits at the German end, not the Czech one. This project's pilot-scale break-even fee, €1.30, lands exactly at the low-wage benchmark despite operating in a high-wage market - and it keeps falling from there, not because the mechanism changes, but because fixed costs spread across more volume as the system scales: €1.08 at district scale, €0.97 city-wide. The honest way to state it: this system delivers high-wage-country service at low-wage-country cost, and the gap only widens with scale.

Budget - Phase 0, the smallest testable unit

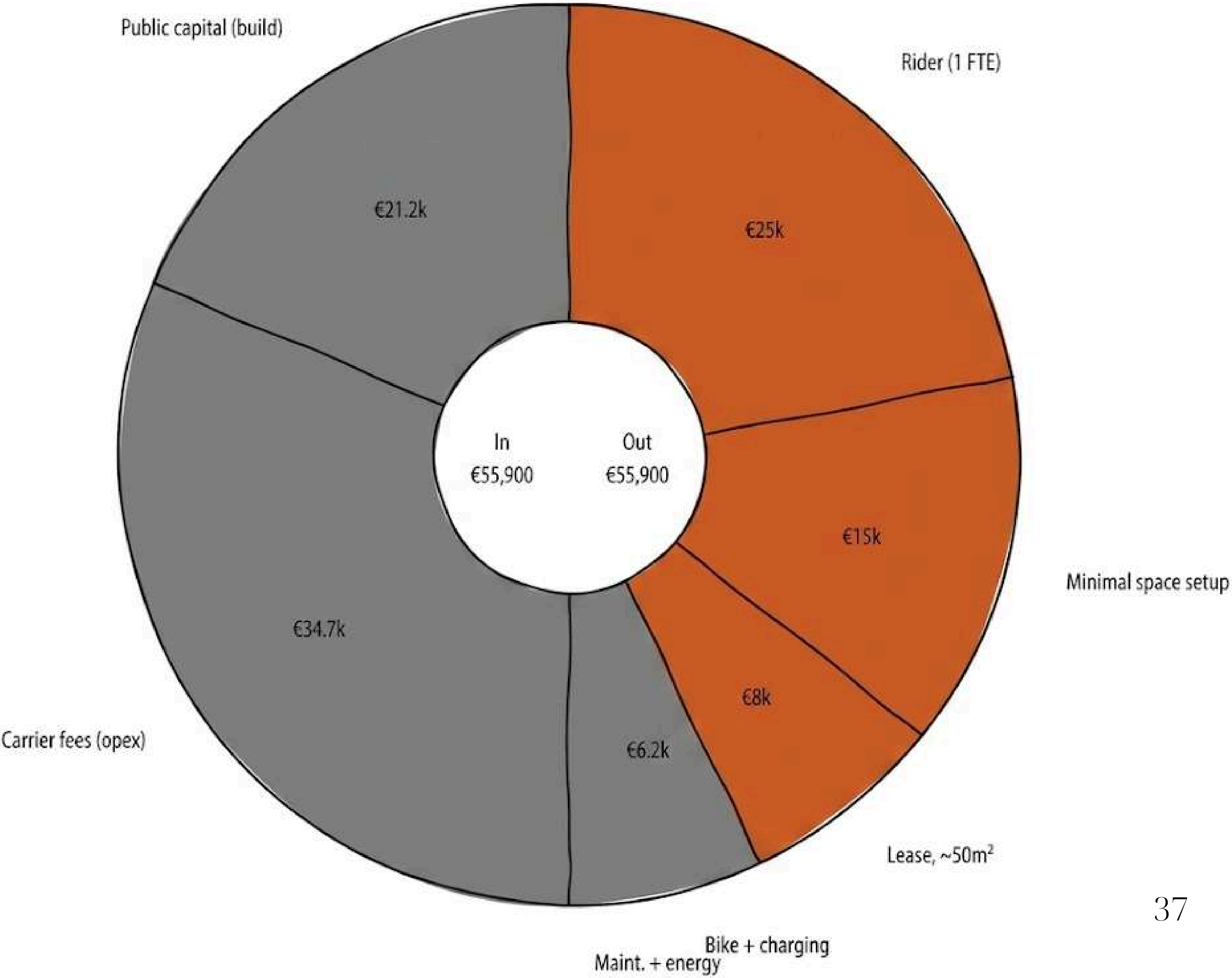
€ 55 , 9 0 0 T O F I N D
O U T I F T H E
M E C H A N I S M W O R K S ,
B E F O R E A N Y T H I N G
B I G G E R G E T S
F U N D E D

One bike. One microhub-to-curb link. One rider. Run for a full year, at the smallest scale that still counts as a genuine test rather than a gesture. This isn't a symbolic pilot-of-a-pilot - a single real carrier either uses this or doesn't, a single real link either holds up under daily use or doesn't, and that answer is exactly as informative at this size as it would be at eight bikes, for a fraction of the exposure.

The number matters less than where it comes from. Every line in this budget is either a sourced unit cost applied once instead of across a fleet - the bike, the charging socket, the per-day energy rate - or a stated fraction of its own Phase 1 equivalent, scaled down on an explicit, checkable basis rather than guessed at fresh. The space setup is roughly a fifth of the full retrofit scope, because it deliberately skips everything that only earns its cost once volume justifies it - CCTV, welfare facilities, the parts of a real hub that matter at scale but add nothing to answering the one question Phase 0 exists to answer: does the mechanism actually work. Public capital covers the €21,200 to build it. Carrier fees cover the €34,700 to run it for a year. Two sources, no third, no ongoing subsidy in either half - the same financing discipline this project has held everywhere else, just proven first at a scale small enough that being wrong costs almost nothing.

Line,	Amount	How it was decided	Basis
Rider, 1 FTE	€25,000	One part-time or junior rider-coordinator, covering delivery runs and basic operation	assumption
Minimal space setup	€15,000	Roughly one-fifth of the full Phase 1 retrofit scope; no CCTV or welfare facilities yet	assumption
Lease, ~50m²	€8,000	Scaled from the Phase 1 lease rate per square metre	assumption
Bike + charging	€6,200	One commercial e-cargo bike plus one charging socket, same unit cost as Phase 1	sourced
Maintenance + energy	€1,675	Energy at real per-day rate for one bike over 250 days; maintenance held flat	energy sourced, maintenance assumed

Here is the actual limit, stated plainly rather than left implicit: Phase 0 is not a smaller Phase 1. It's a different question. Phase 0 asks whether the mechanism works at all - does a carrier actually use it, does the link actually function day to day, is the basic economics directionally sound. Phase 1, the fuller €383,000 budget already built, asks whether it works at the scale that actually matters-eight bikes, a real fleet, real staffing, real throughput against the €1.40/parcel and 120,000-parcel thresholds already set at Gate 1. Phase 0 clearing doesn't automatically greenlight Phase 1's spend; it only earns the right to attempt it. That's the actual shape of the dial this project has claimed all along, made concrete in currency for the first time: not one number that scales smoothly upward, but a genuine step function, each step earning the next on its own evidence, at a cost proportional to how much is actually being risked at that step.



Budget - Phase 1, once Phase 0
clears

WHAT IT
ACTUALLY COSTS
TO PROVE THIS
AT REAL SCALE

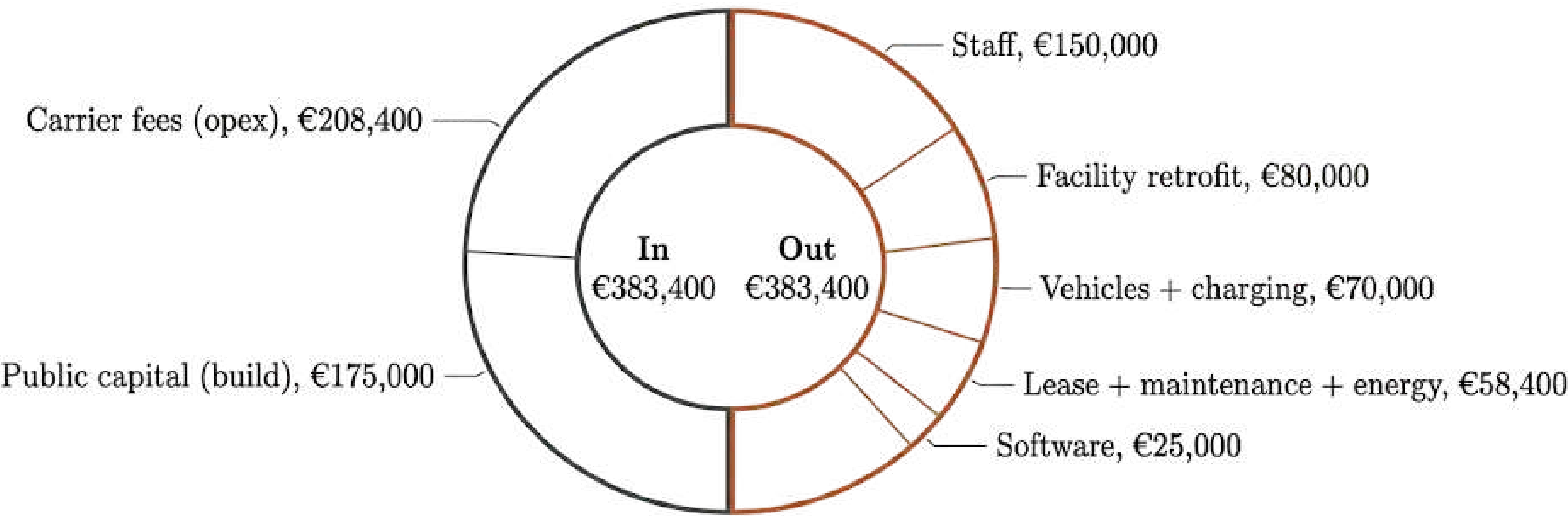
Every figure here is marked by how solid it is - sourced from a real published number, or a stated assumption you can defend on its own terms, never presented as more certain than it is.

Capital expenditure, Year 1: 8 e-cargo bikes at roughly €5,000 each - €40,000. Charging for 8 sockets, roughly €1,200 each, plus a €20,000 grid-upgrade contingency - €30,000. Facility retrofit at full scope - shelving, secure bike storage, CCTV, welfare facilities, the same scope Better Bankside actually built - €80,000. Slot-booking software - €25,000. Total: €175,000.

Operating expenditure, annual: 3 FTE staff-a hub coordinator plus two riders - €150,000. Lease on roughly 300m² of reused space - €45,000, still the single largest unverified figure in the whole model. Energy for 8 bikes - €1,400/year. Maintenance and insurance - €12,000. Total: €208,400/year.

Cross-check: Year 1 total lands around €383,000. The HALLO pilots ran real consolidation centres across two cities, Barcelona and Stockholm, on €530,000 combined-roughly €265,000 per city. This project sits above that for an identifiable reason, not an unexplained gap: HALLO was a research pilot; this includes a full dedicated fleet and permanent staffing from day one.

This is the same discipline as Phase 0, applied at the scale that actually matters. Phase 0 proved the mechanism works. Phase 1 doesn't repeat that question-it asks whether the same mechanism holds up once real volume, real staffing, and real fleet size are behind it, checked against the thresholds already set at Gate 1: 120,000 parcels a year, €1.40 per parcel, three carriers still active. It gets committed because Phase 0 already answered the question this budget can't afford to get wrong.



Line	Amount	How it was decided	Basis
8 e-cargo bikes	€40,000	~€5,000 each, commercial CE-certified range	sourced
Charging + grid contingency	€30,000	8 sockets at ~€1,200 each, plus upgrade contingency	sourced range
Facility retrofit	€80,000	Full scope matching Better Bankside’s documented retrofit	assumed cost
Slot-booking software	€25,000	Off-the-shelf SaaS plus integration	assumption
3 FTE staff	€150,000	Coordinator plus two riders, full fleet scale	assumption

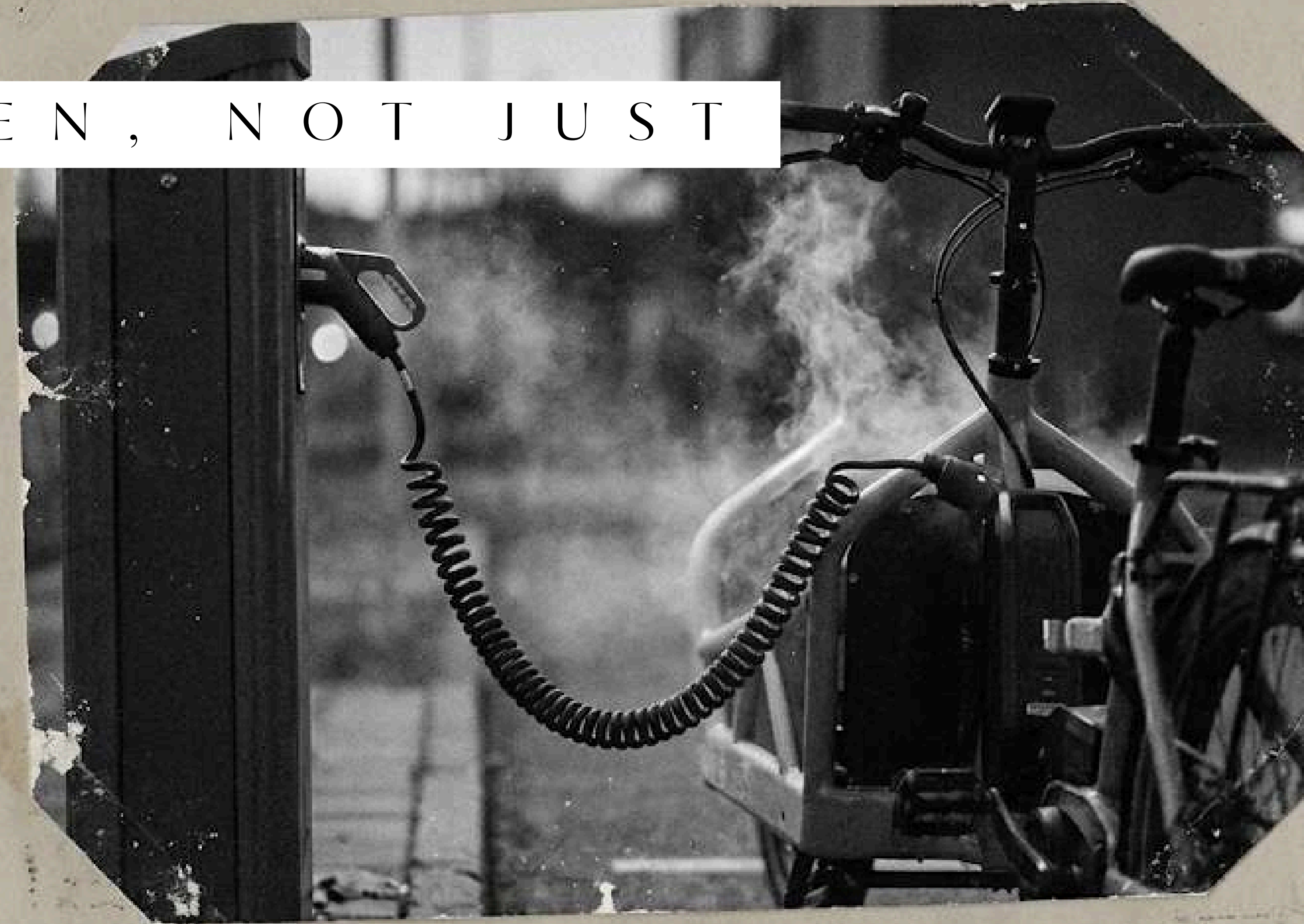
Year 1 total: €383,000, cross-checked against HALLO’s real €530,000 two-city pilot budget (~€265,000/city) — higher for a stated reason: full dedicated fleet and permanent staffing, not an unexplained gap.

Conclusions

WHAT ACTUALLY GOT PROVEN, NOT JUST PROPOSED

Every claim in this project traces to something checkable, not asserted. The break-bulk wall isn't a metaphor - it's what happens, measurably, when a hundred invisible sheds get collapsed into one visible edge by a regulation already live in 18 Dutch cities. The three-layer system - boundary hub, microhub, counterweighted connector - wasn't invented from a blank page; every piece traces to a specific case that already tested it: Beaugrenelle's reused space, Gnewt Cargo's neutral operator, Mail Rail's 76 years of proof that narrow scope survives.

The system was stress-tested against three real failure modes, not hypothetical ones, and it didn't survive all of them cleanly - a heat wave and a packaging mandate collide on the same grid connection, and that collision is named, not hidden. The financing is a stated bet, checked against the exact conditions the field's own literature says determine survival, all three confirmed true for this site. The budget starts at €55,900, not €383,000 - proving the mechanism before committing real money to it, the same discipline applied to spending that's been applied to everything else.



Conclusions

THE TRUCK WAS NEVER COMING - THE SYSTEM
THAT REPLACES IT ALREADY IS

Two people, addressing the same room within 48 hours of each other in December 2019, reached for the same metaphor without coordinating it: a moon landing, a promise with no room to fall short gracefully. That ambition was never the missing piece. What neither speech addressed - what this project exists to answer - is where the mess lands when a continent-scale target meets one real street.

It lands at a boundary hub reachable without crossing a line. At a microhub built into a viaduct nobody was using. At a curb booked by the minute instead of claimed by whoever gets there first. At a KPI chosen specifically because the easy one would have flattered the wrong thing. None of it is finished - the lease cost is still unverified, the connector's real-world capacity is still a bet, and this project says so plainly rather than papering over it. But at pilot scale, for €55,900, that's exactly what gets tested first, before anything larger is asked to be trusted.

Eighteen cities are already enforcing this regulation. Twenty-nine will be by 2030. The system built here doesn't need to be reinvented for each one - it needs to be run again, at whatever scale that city's own dial is set to.

