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From Commuters to Explorers: Modal Inertia, Behavioral Commitment, and the Segmentation Logic of Flat-Rate Urban Mobility

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ABSTRACT

Urban residents do not fail to explore their cities because transit infrastructure is absent — they fail because behavioral habituation compresses their effective activity spaces far below objective accessibility boundaries. We term this condition modal inertia. This paper reports on a three-week social experiment in which 559 residents of a high-density metropolitan residential district in western Tokyo received unlimited access to a Digital Mobility Pass integrating a dedicated light rail line, four bus routes, and an electric micro-mobility sharing service for 2,000 JPY. Drawing on post-experiment survey data from 237 respondents (42.4% response rate) and 6,983 digital ticketing activation logs, we identify a four-segment behavioral typology and demonstrate that the number of transport modes actively combined, not demographic variables, is the primary predictor of behavioral change. Tri-modal users reported daily spending increases at 47.8%, against 33.3% for single-mode rail/bus users — a 43.5% relative differential sustained across both daily and leisure consumption contexts. The design implication is precise: MaaS interventions should be engineered to dissolve modal inertia, not merely to expand modal choice.

Keywords: MaaS, Modal inertia, Behavioral typology activity space, Urban exploration flat-rate mobility, Social experiment

INTRODUCTION

On the final weekend of a three-week pass experiment in a residential district of western Tokyo, a 47-year-old commuter traced a wide arc through three neighborhoods by combining suburban rail, electric micro-mobility, and the Setagaya Line — a circuit with no practical transit purpose. He stopped for lunch at a sushi restaurant in Sangenjaya where he spent 3,000–4,000 JPY, and described the afternoon as satisfying a personal need to "increase the resolution of the city." He had never been to that restaurant. He would not have gone without the pass.

A few kilometers away, on the same weekend, a different participant holding the identical pass took the bus home from work and went to bed. Her travel frequency did not change. Her spending did not change. She described the pass as having provided adequate value for the price paid.

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Between these two users — both residents of the same ward, both holding the same 2,000-yen ticket, similar in age and household type — lies the central puzzle this paper sets out to resolve. The answer has practical consequences for every mobility integration initiative currently under development across the world's dense urban districts.

We propose the concept of modal inertia to name this condition: the self-reinforcing tendency of urban transit users to confine movement to a single habituated modal corridor, even when alternative modes are physically and financially accessible. The pass experiment introduced a structural perturbation: for 2,000 JPY, paid in advance, every mode in the bundle became free at the point of use. What determined how far any given user traveled from their habitual corridor was not age, gender, or residential tenure. It was the number of modes they actually combined.

Section 2 develops the theoretical account of modal inertia. Section 3 describes the experimental design. Section 4 presents the segmentation analysis, leading with the demographic null finding before presenting the modal diversity gradient. Section 5 discusses design implications and limitations. Section 6 concludes.

THEORETICAL BACKGROUND

Activity Space and Its Compression

The concept of activity space — the spatial envelope within which an individual performs the routine behaviors of daily life — was developed by Dijst (1999) and formalized by Schönfelder and Axhausen (2003) as a framework for measuring the lived geography of urban residents. Activity spaces contract when movement is costly in time, money, or cognitive effort, and expand when those costs fall.

For rail-anchored commuters in high-density urban districts, activity space compression follows a predictable logic. The primary rail corridor becomes over-represented in the cognitive map, while adjacent neighborhoods accessible by bus or micro-mobility remain technically reachable but psychologically distant — not because objective distance has increased, but because the marginal cost of lateral movement involves a modal switch that per-ride pricing makes feel more deliberate than it is.

Modal Inertia: Definition and Mechanism

Habit theory provides the proximate mechanism. Wood and Neal (2007) demonstrate that habitual behaviors are triggered automatically by contextual cues. The morning commute script specifies the familiar mode; alternative modes are nominally available but not, in any practical sense, considered. No negative preference for the bus or e-scooter is operating here — simply the absence of any behavioral pathway that includes them.

Modal inertia is this condition at scale: multi-modal infrastructure exists in physical fact while mono-modal behavior persists in behavioral fact. Flat-rate bundling addresses both sides simultaneously: it eliminates per-trip pricing that makes each modal excursion a discrete financial decision, and the sunk-cost structure of advance payment creates a commitment effect that primes users to seek out the full range of their pass before it expires.

Segmentation and the Limits of Demographics

The dominant paradigm in transit user segmentation remains demographic (Beirão & Sarsfield Cabral, 2007; Paulley et al., 2006). Age, gender, income, and household structure have served as the primary variables through which planners predict behavioral response to service changes. What our experiment tests is whether changing the modal environment, without targeting any specific demographic group, produces behavioral change that demographic variables cannot have predicted.

THE EXPERIMENT

Design and Participants

The experiment was conducted between January 27 and February 16, 2025 (21 days) in a high-density residential district of western Tokyo. A pre-sales window ran from January 8 to January 22, during which 559 Digital Mobility Passes were sold via a commercial mobile ticketing platform at 2,000 JPY. The pass granted unlimited access to one light rail line, four bus routes operated by two competing bus companies, and up to 21 electric micro-mobility rides of up to 30 minutes each. No public subsidy was involved; revenues were distributed to participating operators according to usage-linked formulae.

Approximately 84% of purchasers were residents of the target ward. Single-person and couple households without children accounted for roughly 76.6% of participants. Age distribution showed standard working-age concentration, with users aged 60 or above significantly underrepresented — a pattern whose behavioral implications are discussed in Section 5.3.

Data Sources and Segmentation Method

Three data streams were integrated for analysis. The mobile ticketing platform generated 6,983 activation events, of which 75.6% occurred within 200 meters of a known station or bus stop node. The micro-mobility provider supplied independent ride logs. Post-experiment survey responses were collected from 237 of the 559 pass holders (42.4%), covering spending changes, travel frequency, modal satisfaction, and open-ended experience narratives.

Users were assigned to four mutually exclusive segments based on observed modal usage profiles: Tri-modal Hybrid Users (light rail, bus, and micro-mobility; n = 69), Bi-modal Hybrid Users (any two modes; n = 102), Single Rail/Bus Users (n = 30), and Single Micro-mobility Users (n = 36). Between-segment comparisons used chi-square tests and one-way ANOVA; monotonicity of the modal diversity gradient was assessed with Jonckheere–Terpstra trend tests.

RESULTS

The Demographic Null

The clearest finding in the demographic analysis is a negative one, and it deserves to be stated plainly: no statistically significant differences in behavioral outcomes were observed between Hybrid and Single-mode segments on the basis of age, gender, household structure, or length of residence in the ward. Working-age users across the 20–59 age range showed near-identical distributions of modal usage intensity and behavioral change.

This null finding is not a methodological failure. It is an empirical result with a direct implication: if a transit operator were to decide which users to recruit for a future flat-rate pass experiment on the basis of demographic profiling, the data would not support that decision. The demographic profile of users who changed their behavior is essentially indistinguishable from the profile of users who did not.

The one exception is significant. Users aged 60 or above appeared in Tri-modal Hybrid segments at substantially lower rates than their share of the pass-holding population would predict. We return to the mechanism in Section 5.3.

The Modal Diversity Gradient

Table 1 presents behavioral outcomes by segment across three dependent variables: daily spending change, leisure spending change, and travel frequency change during the experiment period.

Table 1: Behavioral outcomes by modal usage segment.

Segment	n	Daily Spending Increased (%)	Leisure Spending Increased (%)	Travel Frequency Increased (%)	Mean Modes Combined
Tri-modal hybrid users	69	47.8	43.5	60.9	3.0
Bi-modal hybrid users	102	40.6	38.2	52.0	2.0
Single — Rail/Bus only	30	33.3	30.0	36.7	1.0
Single — Micro-mobility only	36	38.9	38.9	41.7	1.0
All survey respondents	237	41.8	—	—	—

Source: Post-experiment survey (n = 237); digital ticketing activation logs (N = 6,983); micro-mobility ride logs.

The gradient is monotonic across all three outcomes. For daily spending, the proportion of users reporting an increase rises from 33.3% (Single Rail/Bus) to 40.6% (Bi-modal) to 47.8% (Tri-modal) — a 43.5% relative increase from trough to peak. For travel frequency, the gradient is steeper: 36.7% rising to 52.0% and 60.9%, a 66% relative differential. The Jonckheere–Terpstra trend test confirmed monotonicity ($p < .01$). Single Micro-mobility Users sit between Rail/Bus singles and Bi-modal users — suggesting micro-mobility novelty carries an independent behavioral activation premium above established public transport alone.

What Tri-Modal Users Actually Did

The quantitative gradient takes on texture when read alongside survey narratives. Tri-modal users did not simply use three modes; they combined them in ways that produced qualitatively different spatial experiences from those available within any single mode's network.

The most striking feature of Tri-modal accounts is systematic urban re-exploration that intensified rather than diminished across the three weeks. A 28-year-old resident described researching the district's bus and rail maps "thoroughly" in the first week, then deploying the resulting knowledge to execute a sequence of visits in the final week — extending routes to neighborhoods that required the light rail and micro-mobility to be used at maximum geographic extension simultaneously. "Just about in range," he noted, suggesting the known boundary of the network had become a target rather than a limit.

A 39-year-old woman had not planned to explore; she had planned to commute. Finding herself waiting for a delayed bus, she switched to the light rail — and discovered that the dwell time at an intermediate station gave her time to visit a café she had passed dozens of times without entering. "The resistance to getting off at intermediate stops disappeared," she said. "The thought started occurring to me: maybe I could get off here."

Single-mode users rarely described experiences of this kind. Their accounts were marked by the language of adequacy — the pass was "fine," a specific mode "convenient," the experiment "reasonable value." The category of discovery was largely absent. This linguistic difference between segments mirrors the quantitative one.

The Spending-Mode Relationship

Of the 41.8% of all respondents who reported spending increases, the dominant category was food and beverage. This is not incidental. Dining is the economic activity most sensitive to locational novelty — restaurants are discovered, not sought out by prior knowledge, and discovery requires mobility. What Tri-modal users gained was not primarily access to commercial venues unavailable before; they gained a behavioral disposition toward lateral movement that expressed itself economically through the food-and-drink sector that rewards it most immediately.

DISCUSSION

Designing for Modal Inertia, Not Modal Choice

The modal diversity gradient documented in Section 4 might reflect pre-existing differences in behavioral orientation — that exploratory users gravitated toward multi-modal usage because they were already exploratory, not because the multi-modal structure made them so. We cannot exclude this interpretation with the current data; no pre-experiment behavioral baseline was collected.

The more productive reading, consistent with the qualitative evidence, is that the flat-rate architecture created opportunities for modal adoption that users took up to varying degrees, and that variation in uptake was shaped by the design of the pass rather than the constitution of the user. The woman who switched modes because her bus was delayed did not plan to explore; the structure placed her in a situation where exploration was costless. The design made the explorer.

This implies that the primary variable under a designer's control is interface architecture: the ease of initiating a first trip on an unfamiliar mode, the placement of intermodal transfer nodes, the legibility of the network as a unified whole. Every friction point is a point at which modal inertia can reassert itself.

Translating this into practical terms, a pass designed to dissolve modal inertia should address at least four implementation variables. First, onboarding frictionlessness: the effort required to initiate a first trip on an unfamiliar mode must be minimized at the moment of pass receipt — ideally through in-app activation rather than email-delivered coupon codes that require a separate login sequence. Second, network legibility: the pass should be accompanied by a unified multi-modal map that visualizes all included services as a single spatial system, rather than presenting each operator's network in isolation. Users who cannot mentally represent the combined network cannot exploit it. Third, node co-location: intermodal transfer points — where a user can alight from rail and immediately access micro-mobility — should be explicitly marked and, where possible, physically co-designed with short dwell times and clear wayfinding. Fourth, pricing within the commitment activation range: based on the WTP data reported in companion studies, a 2,000–4,000 JPY range activates anticipatory commitment for the target demographic without creating a meaningful access barrier. Operators seeking to maximize behavioral activation — rather than trial uptake volume — should price within this band rather than toward zero.

The Commitment Effect of Pre-Payment

The behavioral economics literature has treated the sunk cost effect primarily as an error (Arkes & Blumer, 1985). The pass experiment inverts this framing. The 2,000 JPY sunk at purchase did not distort decision-making; it structured it productively. Multiple participants described scheduling their lives around the pass — dedicating specific evenings to solo dining, planning weekend routes in advance, monitoring elapsed rides against the 21-ride ceiling.

This mechanism has a design consequence currently undertheorized in the MaaS literature. The case for free or subsidized trial access to new transport modes is intuitively compelling — but it may produce thinner behavioral engagement than paid access at a price point that registers as a commitment. Whether a lower price would have produced shallower exploration and weaker spending outcomes is a question only a price-randomized experiment could answer.

Who Remains Inert: The 60-Plus Exception

The underrepresentation of users aged 60 and above in Tri-modal segments is attributable to micro-mobility adoption barriers. Physical safety concerns about e-scooters and e-bikes are well-documented in this population (Eccarius & Lu, 2020). Because Tri-modal status requires micro-mobility use under the current pass design, users who cannot adopt micro-mobility are structurally capped at Bi-modal regardless of their behavioral disposition toward exploration. A pass architecture incorporating accessible alternatives — demand-responsive minibus, cargo bike, or shared vehicle — might extend the Tri-modal premium to a broader age range.

What We Cannot Yet Say

Several limitations qualify the conclusions reported here. First, the behavioral persistence question: does the activity space expansion observed during the experiment survive the pass's expiration? The experiment collected no follow-up data; a survey at 60 and 90 days post-experiment would determine whether modal inertia re-establishes itself once the flat-rate structure is removed, or whether the new routes and modes discovered during the experimental window become incorporated into habitual behavior. This distinction matters substantially for the long-term policy case for MaaS investment.

Second, the quantity limitation: this experiment measured the binary direction of spending change — whether participants spent more, less, or the same — but not the magnitude. Transaction-level spending data integrated with the digital ticketing logs would permit an economic impact model capable of estimating aggregate local consumption change per pass sold, substantially strengthening the commercial viability case.

Third, self-selection bias: the 559 participants who purchased the pass are not a random sample of the district's residents. They may overrepresent behavioral early adopters — individuals with stronger baseline interest in urban exploration — relative to the median resident. The behavioral outcomes reported here describe what happened among this self-selected purchaser population; they should not be directly extrapolated to the full district population without adjustment.

Fourth, the generalizability question: the experiment was conducted in a high-density, high-income residential district served by well-developed existing public transport. The extent to which the modal inertia mechanism, and the four-segment typology derived from it, apply to lower-density suburban districts, lower-income populations, or infrastructure-scarce urban environments is not addressed by this study and represents a necessary direction for comparative future research.

Fifth, weather dependency: the experiment period coincided with relatively favorable winter weather in the study district. Micro-mobility usage logs showed measurable sensitivity to rain events, with same-day LUUP activations declining on precipitation days. A replication in summer months or under more variable weather conditions would test whether the Tri-modal behavioral premium is partially a seasonal artifact.

CONCLUSION

The 47-year-old who used a pass to "increase the resolution of the city" was not an exceptional person. He was a person in an exceptional environment — one that made the city's full texture accessible for a fixed, pre-paid cost, and that bundled three modes together such that using one without the others felt like leaving value on the table. His behavior was designed. Not by intent, but by architecture.

The four-segment typology this paper proposes — Tri-modal Hybrid, Bi-modal Hybrid, Single Rail/Bus, Single Micro-mobility — is not a classification of people. It is a classification of behavioral outcomes produced by a shared structural intervention. The monotonic gradient from 33.3% to 47.8% in spending increase, and from 36.7% to 60.9% in travel frequency increase, describes the dose-response relationship between modal diversity and behavioral change — a relationship that is in principle designable.

The challenge is not to identify users who are predisposed to explore and give them better tools; it is to create structural conditions that make exploration the path of least resistance for users who, in any other environment, would take the bus home and go to bed. The city has more resolution than most of its residents know. The work of urban mobility design is to let them find it.

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