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# Impact of Digital Flat-Rate Mobility Passes on User Exploratory Behavior: A Case Study of Strategic Multimodal Integration in Urban Residential Districts

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## ABSTRACT

Urban commuters are largely governed by behavioral inertia — the tendency to adhere to routine transit paths in order to minimize cognitive load and incremental cost. This rigidity systematically bypasses the peripheral "inter-hub" districts that exist between major rail nodes, suppressing local economic activity despite their cultural and commercial potential. This study investigates how a digital flat-rate mobility pass, deployed through a strategic consortium of three competing private railway operators and multiple micro-mobility providers in a high-density Tokyo residential district, disrupts this inertia. Drawing on Cognitive Load Theory (Sweller, 1988) and choice architecture principles (Thaler & Sunstein, 2008), we analyze behavioral data from 559 pass holders over a three-week experiment. Results demonstrate that eliminating marginal per-ride costs induced a measurable shift from efficiency-driven commuting to discovery-oriented exploration: 38.4% of users utilized three or more transport modes per journey, average local spending increased by 1,757 JPY per person, and 62.5% of respondents visited commercial destinations they had never previously accessed. These findings establish multimodal digital integration as a scalable instrument for regional revitalization and human-centered Smart City governance.

**Keywords:** MaaS, Multimodal transportation, User experience (UX), Behavioral transformation, Urban revitalization, Social experiment

## INTRODUCTION

In the field of urban planning and human factors, "behavioral inertia" remains a significant obstacle to optimizing metropolitan mobility ecosystems. Most urban commuters operate within a state of "bounded rationality," wherein they adhere to rigid, routine-based transit paths to minimize cognitive load and incremental financial costs (Simon, 1955). This psychological heuristic, while efficient for individual time management, creates a systemic "hub-and-spoke" dependency that concentrates economic and social activity around major transit nodes while leaving peripheral areas underserved. While large-scale transit hubs facilitate high-volume movement, this efficiency often comes at the severe cost of the "economic stagnation" of peripheral districts. These "inter-hub" areas, located between major rail

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nodes, frequently possess significant cultural and commercial assets — local shrines, independent storefronts, community gathering spaces — but remain psychologically distant to commuters who are locked into efficiency-driven, rail-centric routines. The result is a structural paradox: urban spaces rich in potential that are rendered effectively invisible by the cognitive architecture of everyday mobility.

The emergence of Mobility as a Service (MaaS) has promised to dissolve these geographic and organizational silos by integra ting disparate transportation services into seamless, user-centric digital platforms. However, contemporary MaaS implementations frequently focus on technical API integration and backend data-sharing, neglecting the fundamental psychological drivers of human movement. From a transaction cost perspective (Williamson, 1981), the "friction" of multimodal transit is not merely monetary; it encompasses the multifaceted cognitive effort of route planning, the anxiety of navigating unfamiliar transit modes, and the persistent "pain of payment" associated with per-ride fee structures. Each of these friction points independently suppresses exploration; in combination, they constitute a formidable barrier to any behavioral shift away from established commuting routines.

This paper investigates how a digital flat-rate pass, implemented through a strategic consortium of three major private infrastructure operators and electric micro-mobility sharing services, acts as a powerful catalyst for "exploratory behavior." By neutralizing the marginal cost of travel and unifying disparate services within a single digital interface, we hypothesize that the urban environment can be redesigned to encourage spontaneous visits to local assets — transforming routine commuters into active regional participants. The intervention thus addresses behavioral inertia not through regulation or physical infrastructure investment, but through a deliberate redesign of the incentive architecture governing everyday movement decisions.

## THEORETICAL BACKGROUND: COGNITIVE LOAD AND MAAS

Human factors in transportation are deeply influenced by Cognitive Load Theory (Sweller, 1988), which distinguishes between intrinsic load — the inherent complexity of a task — and extraneous load, which is imposed by the design of the environment in which the task is performed. In a fragmented mobility environment, a single journey requiring transitions between multiple platforms (e.g., from heavy rail to a municipal bus, and finally to an e-scooter) imposes a high extraneous cognitive load through the cumulative demands of platform-switching, payment processing, and real-time route recalculation. When this load exceeds the user's available mental bandwidth, they instinctively default to simpler, "path of least resistance" transit modes — typically rail-only or private vehicle paths — even when these are demonstrably less optimal for reaching specific destinations. The consequence at the urban scale is a systematic compression of the effective activity space of the average commuter.

The "Threshold of Exploration" in an urban space is further governed by perceived switching costs, which extend beyond the cognitive domain into motivational and behavioral dimensions. According to the Theory of

Planned Behavior (Ajzen, 1991), behavioral intent is a function of attitudes toward the behavior, subjective norms, and perceived behavioral control. If the effort to access a new transport mode is perceived as high — due to complex registration requirements, unfamiliar payment interfaces, or fragmented service ecosystems — the behavioral intent to use it remains low regardless of the user's underlying interest. Our research addresses these barriers by utilizing a unified digital interface to redesign the "choice architecture" of the city (Thaler & Sunstein, 2008). By providing a "pre-paid" and "all-access" environment, the intervention seeks to transform the user's perception of the city from a series of disjointed cost-centers into a seamless, accessible utility. In this reframed environment, the cognitive and financial costs of exploration are effectively sunk, shifting the user's calculus from "should I take this detour?" to "what have I not yet discovered?" This study evaluates how systematically lowering these cognitive and financial thresholds can expand a user's "Activity Space" and, in doing so, revitalize regional economic vitality in areas that conventional transit patterns have rendered marginal.

## METHODOLOGY

To evaluate the impact of digital integration on behavioral transformation, we conducted a large-scale social experiment in a high-density urban residential district in Tokyo, characterized by a complex intersection of three major private railway networks. The district was selected on the basis of its structural characteristics: a convergence of competing transit territories that had historically produced a fragmented commuter experience, leaving commercially and culturally significant inter-hub areas under-visited despite their proximity to major stations. This setting provided a natural context in which the behavioral effects of a unified digital mobility intervention could be isolated and measured against a clear baseline of incumbent commuting patterns.

### Participants and Setting

The experiment targeted active commuters and local residents who frequently navigate the target district. During a two-week pre-sales window, a total of 559 "Digital Mobility Passes" were sold at a fixed price of 2,000 JPY. This pass granted users unlimited access to a designated rail line (the "backbone" of the area), multiple municipal bus routes, and a limited bundle of rides on electric micro-mobility sharing services (e-scooters and e-bikes) for a continuous three-week period. The pricing strategy was deliberate: unlike previous free-of-charge social experiments in the MaaS domain, the monetary commitment of the participants ensured that the resulting mobility data reflected genuine market demand and high-intent user behavior rather than opportunistic take-up driven by the absence of cost. The 2,000 JPY price point was calibrated to represent meaningful but accessible expenditure for the target demographic, consistent with the cost of two to three standard rail journeys within the district.

### Data Collection and Analysis

A hybrid methodology was employed to capture the multidimensional behavioral and psychological effects of the intervention. The three data streams were designed to be complementary: behavioral logs provided objective ground truth on movement patterns, survey data provided access to subjective experience and motivational shifts, and economic impact data connected mobility changes to measurable downstream outcomes.

1. **Quantitative Behavioral Data:** Tracking data was collected via the ticketing application to analyze "intermodal connectivity," measuring the frequency, sequence, and combination of transport modes used across individual journeys.
2. **Qualitative Surveys:** A post-experiment survey achieved a 58.7% response rate (n=328), measuring shifts in "Psychological Ownership" of the urban space and perceived cognitive barriers to exploration. Open-ended responses were coded thematically to identify dominant experiential patterns.
3. **Economic Impact Analysis:** Participants reported changes in spending patterns and discovery of new local assets through structured survey items benchmarked against their self-reported pre-experiment routine behavior.

## RESULTS

### Ticket Sales and User Engagement Metrics

The experimental "Digital Mobility Pass" was offered at a price of 2,000 JPY (including tax). During the two-week sales window, the project achieved a strong market reception with 559 tickets sold, indicating genuine demand for unified multimodal access at a commercially viable price point. This result is particularly notable because it was achieved without advertising expenditure beyond the existing communication channels of the participating operators, suggesting that latent demand for integrated mobility solutions exists within the target demographic. To capture the psychological and behavioral shifts induced by the intervention, a comprehensive post-experiment survey was conducted, yielding a 58.7% response rate (n = 328). This robust participation rate ensures that the findings are representative of the active user base within the district and provides a sufficiently large sample for meaningful disaggregation by user segment and behavioral pattern.

### Shifts in Mobility Patterns and Connectivity

The data analysis focused on how the integration of rail, bus, and micro-mobility affected intermodal connectivity — specifically, the degree to which users combined modes that they would not have combined under conventional pay-as-you-go conditions.

**Micro-mobility as a Gateway:** According to the mobility logs, the average user completed 2.6 trips using electric micro-mobility sharing services over the three-week period. For many participants, this represented their first sustained experience with e-scooters or e-bikes, indicating a significant "Trust Transfer" effect from the major railway operators who endorsed and co-branded the pass. The bundling of micro-mobility with familiar, high-reliability transit infrastructure effectively lowered the perceived risk of adopting an unfamiliar transport mode.

**Intermodal Synergy:** Detailed route analysis (based on mobility logs) identified significant synergy between the designated railway line and specific bus routes serving the inter-hub zones. Approximately 38.4% of journeys involved three or more distinct modes, effectively bridging the "connectivity gaps" between the five major transit nodes in the district. This rate substantially exceeds typical multimodal usage figures in comparable urban settings, where the friction of fragmented payment systems ordinarily suppresses cross-modal behavior.

**Weekend vs. Weekday:** Movement was particularly high during weekends, with a notably higher proportion of multi-mode journeys recorded on Saturdays and Sundays. This pattern suggests that the flat-rate structure encouraged "leisure-based roaming" — deliberate, discovery-oriented exploration — rather than merely optimizing existing commuting efficiency.

## Quantifying the economic impact and discovery behavior

One of the most significant and practically consequential findings was the pass's demonstrated ability to stimulate local economies by expanding the users' effective activity space beyond the conventional radius of the major transit hubs.

**Increased Spending:** Quantitatively, users reported an average increase in spending of 1,757 JPY per person during their visits to the area compared to their self-reported routine spending patterns. For a significant portion of users, this represented a deliberate decision to explore and patronize local amenities specifically because the "transportation cost" of reaching them had been neutralized. The pass thus functioned not only as a mobility product but as a local economic stimulus instrument.

**Discovery of Local Assets:** Qualitatively, 62.5% of respondents stated they visited "new shops or spots" for the first time during the experiment period. The mobility logs corroborated this self-report by showing measurably increased foot traffic in the inter-hub zones — areas located between major stations that are typically bypassed by routine commuters following direct rail corridors. This "discovery effect" represents a direct conversion of behavioral change into economic activity for previously overlooked commercial areas.

**User Satisfaction (NPS):** The overall Net Promoter Score (NPS) for the pass experience was strongly positive, with users specifically and repeatedly praising the "freedom of movement" and the "psychological safety" provided by the flat-rate system. The absence of per-ride cost anxiety was consistently cited as the primary driver of satisfaction, reinforcing the theoretical framing of the intervention as a deliberate removal of the "pain of payment."

### User Segment Characteristics

Analysis of the survey data and mobility logs identified a key segment of "Utility Maximizers" — users who approached the flat-rate pass with a conscious strategy of value extraction. This group, representing a meaningful minority of the total participant base, viewed the pass similarly to an "all-you-can-eat" service, deliberately increasing their number of stops and mode combinations in order to "maximize the value" of their 2,000 JPY investment. While this motivation differed in character from the more spontaneous discovery behavior observed in the broader user population, the downstream behavioral outcomes were largely identical: increased intermodal usage, higher visit rates to inter-hub areas, and elevated local spending. This convergence of motivated and spontaneous exploration around similar behavioral outcomes suggests that the flat-rate structure is robust across diverse psychological orientations toward consumption and value.

## DISCUSSION

### The "Flat-rate Effect" and Gamification of Urban Movement

The experimental results provide strong validation of the hypothesis that eliminating marginal costs per ride induces a significant and measurable psychological shift in how users relate to the urban mobility environment — a shift we term "permission to explore." In standard pay-as-you-go transportation models, users are continuously subjected to a process of "calculative evaluation," weighing the monetary cost of each additional journey segment against its perceived utility. This constant economic monitoring is cognitively demanding in its own right and acts, via the mechanism Thaler (1985) identified as the "pain of payment," as a persistent inhibitor of discretionary local area exploration. The pain is not merely financial; it is attentional, drawing cognitive resources away from the experience of the urban environment and toward the management of incremental expenditure.

By introducing a flat-rate digital pass, the intervention effectively suspended this calculative mode for the duration of the experiment. The observed transition from cost-performance calculation to a "discovery-oriented" mindset was consistent across user segments and corroborated by both quantitative behavioral logs and qualitative self-report. Participants described the psychological effect as a form of "value-maximization" or an "all-you-can-eat" mentality, expressing a desire to extract maximum value from their fixed investment by proactively increasing the number of stops and modes used. This behavioral pattern is consistent with the gamification literature, where fixed-cost structures with open-ended outcomes transform consumption into a form of play in which each additional discovery is perceived as a "win" rather than an incremental expense.

> *"Because the marginal cost was zero, I felt free to get off at a station I usually skip just to see what kind of cafes were there. It turned my usual commute into a treasure hunt." (Participant feedback, P21)*

## Trust Transfer and the Reduction of Technological Anxiety

A critical and theoretically significant finding of this research is the "Trust Transfer" effect in multimodal transitions. While micro-mobility services — e-scooters and e-bikes — offer substantial flexibility as last-mile and inter-hub connectors, they have historically suffered from a pronounced "reliability gap" in the perceived mental models of first-time and infrequent users. Concerns about safety, mechanical reliability, and navigational complexity constitute meaningful barriers to adoption, particularly among users whose transit behavior is anchored in the established reliability of heavy rail infrastructure.

The experimental data demonstrated that users who were initially hesitant to engage with electric micro-mobility adopted these services at substantially higher rates when they were bundled with familiar, high-reliability infrastructure under a single unified interface. This suggests that the brand equity and institutional credibility of the major railway operators were effectively transferred to the emerging micro-mobility platforms through the co-branded digital pass. By centralizing disparate services within a single "Choice Architecture," the intervention simultaneously reduced the Cognitive Load (Sweller, 1988) associated with multi-app navigation and the psychological risk of trying an unfamiliar technology. The digital pass functioned as an institutional guarantor — providing users with the psychological safety needed to experiment with services they would otherwise have avoided, and thereby accelerating adoption curves that would under ordinary market conditions have required years of independent marketing investment.

## Expanding the Perceived "Walking Distance" and Activity Space

The qualitative feedback highlighted a further dimension of behavioral change that extends beyond intermodal connectivity statistics: a fundamental shift in the perceived accessibility of the urban environment. In conventional mobility contexts, the effective "accessible zone" for pedestrians anchored to a rail hub is typically bounded by a 10–15 minute walk — approximately 800 meters — beyond which the cognitive and financial cost of onward travel begins to suppress exploration. This boundary is not merely physical; it is a cognitive artifact of the existing incentive structure, reinforced by each instance of having to consciously decide to pay for an additional short journey.

The integration of bus and micro-mobility through the flat-rate digital pass effectively dissolved this boundary for the duration of the experiment. Participants reported that the "seamless connectivity" provided by the pass

made the entire district feel like a unified, navigable neighborhood (P22) rather than a series of discrete zones separated by friction-laden intermodal transitions. This cognitive expansion of the accessible space — from a hub-anchored 800-meter radius to a district-wide network of connected nodes — was reflected directly in the behavioral data: the 62.5% increase in first-time visits to new spots and the 1,757 JPY increase in local spending per person are quantitative expressions of a qualitative transformation in how users experienced and inhabited the urban environment.

> *"I used to only visit places within 10 minutes of the station. With the pass and an e-scooter, I found a wonderful bakery 1.5km away that I never knew existed. The district felt 'connected' for the first time." (Participant feedback, P22)*

### Strategic Orchestration Over Administrative Initiative

Finally, the institutional architecture of this intervention merits consideration as a governance model in its own right. The success of this multimodal alliance project highlights a broader and consequential shift in Smart City governance: the emergence of private-sector orchestration as a more agile and effective vehicle for social implementation than traditional public-sector-led initiatives. Conventional municipal MaaS projects frequently suffer from the compound delays of multi-agency approval cycles, procurement regulations, and risk-averse institutional cultures — what might be termed "bureaucratic lag" — that compress the window of market opportunity and erode the responsiveness of the intervention to actual user needs.

The private-sector orchestration model demonstrated in this project operated without public subsidy or governmental mandate, relying instead on the alignment of corporate interests around a shared vision of regional asset value. By positioning a neutral orchestrating entity between three competing railway operators, the project created conditions in which cooperation was commercially rational rather than administratively imposed. This model provides a robust and replicable framework for Autonomous Urban Governance — one in which private stakeholders drive social implementation by focusing on User Experience (UX) and the long-term appreciation of regional asset value, rather than on the protection of individual market share.

## CONCLUSION

This research provides empirical evidence that digital mobility integration, when coupled with a strategic flat-rate incentive structure, serves as a potent instrument for both regional revitalization and the psychological reconfiguration of how urban spaces are experienced and inhabited. By fundamentally reducing the financial and cognitive friction associated with multimodal movement, the intervention demonstrated that commuter behavior is not a fixed behavioral constant but a highly malleable response to the incentive architecture of the transportation ecosystem. The successful synchronization of disparate transit modes — ranging from traditional heavy rail and municipal buses to emerging electric micro-mobility services — proved

that a unified User Experience (UX) can effectively bridge the "connectivity gaps" that have historically suppressed economic activity in inter-hub areas, and that this bridging effect produces measurable downstream improvements in local commercial vitality.

The results further highlight the efficacy of private-sector-led orchestration in the social implementation of Smart City initiatives. The collaboration between competing infrastructure operators, facilitated by a neutral orchestrating entity, enabled an agile and user-centric approach that consistently outperformed what traditional administrative frameworks would have been capable of delivering within a comparable timeframe. The observed "Trust Transfer" effect — through which the institutional credibility of established rail operators extended to emerging micro-mobility platforms — and the documented expansion of users' "Activity Space" together suggest that the future of urban mobility lies in the transition from fragmented, mode-specific service provision to a seamless, access-based utility model. This shift not only enhances individual mobility convenience but also revitalizes local storefronts and community assets by converting passive, efficiency-maximizing commuters into active, discovery-oriented regional participants.

Future studies should examine the long-term sustainability of the behavioral changes observed in this experiment — specifically, whether the shift toward exploratory mobility persists after the flat-rate incentive is withdrawn, or whether behavior reverts to pre-intervention baselines once marginal costs are reintroduced. The scalability of the model across urban structures with varying density profiles, demographic compositions, and transit network architectures also warrants systematic investigation. Additionally, as autonomous transit technologies and more diverse forms of micro-mobility continue to emerge, understanding the evolving nature of the "Threshold of Exploration" — and how it can be systematically lowered through design — will be critical for urban planners, policymakers, and private infrastructure operators alike. Ultimately, this study offers a robust and scalable framework for metropolitan areas globally that are striving to implement sustainable, human-centered Mobility as a Service solutions capable of harmonizing corporate growth imperatives with broader societal well-being.

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