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Facility Awareness and Limited Mobility in Shanghai's Peri-Urban Resettlement Areas: A Baseline Study of Type-Based Threshold Effects for Sustainable and Inclusive Mobility

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Abstract

As cities worldwide pursue sustainable and inclusive mobility, understanding the travel behavior of vulnerable populations in peri-urban resettlement areas is essential for designing equitable built environments. In Shanghai, as in many rapidly urbanizing megacities, government-led redevelopment in central Shanghai displaces residents to the urban periphery, creating accessibility deficits and raising transport inclusivity concerns. Using travel diary data from five peri-urban affordable housing communities collected in 2012 (N = 8390)—a critical baseline before major infrastructure improvements—this study documents limited mobility (residents make significantly fewer trips than the city average) and examines its correlates via logistic regression. A core finding is a type-based threshold effect: awareness of a nearby large shopping mall is associated with higher shopping trip frequency (coefficient −0.332, p = 0.024), whereas awareness of small-to-medium supermarkets shows no significant association. This pattern is consistent with elastic demand theory and challenges the assumption that any retail facility improves accessibility equally. Our models explain very little variance (Nagelkerke R^2 = 0.078 for overall trip frequency; 0.048 for shopping frequency). This low explanatory power is itself a diagnostic signal—and a core motivation for our hypothesis-generating approach—indicating that unmeasured psychological (attitudes, perceived behavioral control), social (networks, norms), and technological (e-commerce) factors likely dominate travel decisions—directing future research priorities. Methodologically, the 2012 data provide an uncommon early-stage baseline for policy-induced resettlement, enabling future longitudinal comparisons and mechanism identification (e.g., before/after metro or mall openings). For contemporary policy, the findings suggest a testable hypothesis that anchor-type facilities (e.g., mid-sized community hubs with mixed use, rather than merely small supermarkets) may activate suppressed demand, requiring re-evaluation with recent data and causal designs. Readers should not extrapolate numeric trip rates to today's Shanghai. The primary contributions are theoretical (type-based threshold effects, the anchor-vs.-routine facility distinction, the role of basic spatial awareness) and methodological (historical baseline). The 2012 data predate widespread e-commerce; digital substitution may substantially attenuate these relationships in contemporary contexts.

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1. Introduction

Over the past decades, Chinese megacities have experienced significant spatial restructuring. While the nation continues to urbanize, several megacities—including Shanghai—have entered a phase of suburbanization driven by central-city redevelopment and policy-induced resettlement. Shanghai, with a municipal area of 6340 km^2 and a population exceeding 24 million as of 2015 [1], exemplifies these trends. Residents move to the urban periphery for various reasons: some voluntarily seek modernized housing; others are priced out of the central city; many are forcibly relocated due to demolition and redevelopment programs [2]. Such spatial restructuring reflects broader suburbanization patterns observed in Chinese megacities [3,4].

Peripheral resettlement exacerbates accessibility deficits. Newly developed communities often lack adequate transport options and nearby services, reducing trip frequency and threatening social inclusion. The transport accessibility and social inclusion literature emphasizes that when individuals cannot reach essential destinations (employment, healthcare, shopping) with reasonable effort, they risk exclusion from societal participation [5,6]. Thus, understanding and improving accessibility in these communities is a policy and research priority.

In Shanghai, approximately 30 large-scale affordable housing areas had been developed or planned on the urban periphery by the time of our 2012 survey. These areas are characterized by government-owned land, state-subsidized housing, and policy-driven allocation. Prior research has documented lower trip frequencies among residents in peri-urban affordable housing areas compared to city averages—both in Shanghai [7] and in other Chinese megacities such as Beijing [8]. However, systematic evidence on trip generation rates and their correlates in these contexts—especially during the critical early stage after resettlement—remains limited. Most existing studies have focused on developed countries or on other travel dimensions (mode choice, travel time) rather than on trip frequency. Moreover, the role of residents' awareness of nearby facilities—as distinct from objectively measured accessibility—has received little attention. Critically, no previous study has systematically examined the interaction among subjective cognition, facility typology, and travel frequency in the context of policy-induced resettlement in developing-country megacities. This study directly addresses this gap.

This study pursues three interconnected theoretical objectives that collectively constitute its novelty. First, it shifts the focus from objectively measured accessibility to residents' cognitive awareness of nearby facilities—a dimension largely overlooked in previous peri-urban resettlement research—and tests the hypothesis that this cognitive awareness, rather than objective proximity, is associated with trip frequency. Second, it introduces and examines whether a type-based threshold effect exists: awareness of anchor facilities (large malls) activates suppressed travel demand, whereas awareness of routine facilities (small supermarkets) does not, thereby refining elastic demand theory in the context of peri-urban resettlement. Third, it provides a rare baseline dataset from 2012, capturing mobility constraints before major infrastructure interventions, which enables future longitudinal comparisons and mechanism identification.

Our key cognitive variable is a single-item, binary indicator of facility awareness: whether the resident knows that a large shopping mall exists near their living place. We

explicitly distinguish this crude proxy from the validated, multidimensional construct of perceived accessibility [9] and from the theoretical constructs of the Theory of Planned Behavior (TPB) [10]. We do not claim to have measured perceived accessibility or perceived behavioral control. Instead, we use these frameworks as heuristic lenses to interpret our exploratory correlations and to generate testable hypotheses for future research.

The empirical data were collected in 2012, capturing an uncommon early-stage snapshot when these communities were newly established, and infrastructure gaps were most pronounced. As will be shown, our logistic regression models explain very little variance (Nagelkerke $R^2 \approx 0.078$ and 0.048)—a finding that itself directs attention toward unmeasured psychological, social, and technological factors. Readers should not extrapolate absolute trip rates to today's Shanghai; subsequent infrastructure improvements and digital transformation have substantially altered the context. The primary contributions are theoretical (preliminary correlational support for a type-based threshold effect) and methodological (a rare 2012 baseline for future longitudinal comparisons).

Structure of the paper. Section 2 reviews the literature and outlines our theoretical lens. Section 3 describes the survey sites, sampling procedure, and data. Section 4 presents the logistic regression results for shopping frequency—the core finding—and Section 5 presents the results for overall trip frequency as a complementary analysis. Section 6 discusses implications and limitations and proposes a future research agenda. Section 7 concludes.

2. Literature Review

2.1. Travel Frequency and the Built Environment: Insights from Developed Countries

Studies in developed countries have established that residential location and built environment attributes—such as density, mixed land use, and transit accessibility—significantly influence trip generation rates [11,12]. However, these findings may not directly transfer to peri-urban resettlement areas in rapidly urbanizing developing countries, where policy-induced relocation—rather than voluntary residential choice—plays a dominant role. Moreover, most existing studies have relied on objectively measured accessibility and have rarely examined cognitive factors such as residents' awareness of nearby facilities—a gap this study begins to address.

2.2. China's Suburbanization and Travel Behavior in Affordable Housing Communities

China continues to undergo rapid urbanization, while several megacities (e.g., Beijing, Shanghai, Guangzhou) have entered a suburbanization phase characterized by outward population movement and polycentric development [4,13,14]. This suburbanization is driven largely by central-city redevelopment and the construction of affordable housing on the urban fringe [15]. Large-scale residential areas on the periphery have consequently become a focus of research. We organize the literature into three thematic areas.

On commuting and job accessibility, ref. [16] found that relocation to Beijing's periphery lengthened commute durations, especially for "reluctant" movers. Refs. [3,17] showed that relocation to outlying Shanghai areas dramatically reduced job accessibility while increasing motorized travel and commute times. Ref. [7] characterized social welfare housing communities as automobile-oriented, with the longest work trip travel times among all housing types. More recently, longitudinal evidence from Shenzhen using mobile phone data confirmed that affordable housing transition increases commuting burdens and reduces non-work activity spaces [18]. Focusing specifically on low-income populations, Zhao [19] demonstrated that housing location in Beijing's peripheral affordable housing developments is the dominant determinant of commuting burden, outweighing individual socio-economic characteristics—suggesting that the commuting disadvantage faced by relocatees is structural rather than merely a matter of individual choice.

On mode choice and modal equity, ref. [20] found that relocatees were more inclined to use alternative modes (bike, bike sharing, moped, walking) but had the poorest accessibility to these facilities. Ref. [21] investigated older adults in Fuzhou and found that suburban seniors were more likely to use cars to reach high-quality medical services. Ref. [22] analyzed 12 relocated communities in Nanjing and concluded that higher bus stop density reduced the probability of choosing high-carbon commuting modes. Additional studies have examined public transport use in peri-urban affordable housing areas [23] and the travel patterns of low-rent housing residents in Fuzhou [24].

On policy and trip generation, policy-oriented studies include ref. [25], who argued that travel needs should be a major factor in relocation policies. A series of studies have examined travel behavior and transport policies for different resident groups in large-scale residential areas on the urban periphery [7,23,26–28]. Several studies have directly examined trip generation in peri-urban affordable housing areas. Ref. [29] examined Kunming's suburban residents relocated from the city center and found that subjective factors (attitudes, past behavior, and facility accessibility) positively affected non-work travel frequency.

Residential housing policies in other Chinese cities have also been shown to influence car ownership and trip chaining. In Hangzhou, residents of commercial housing were more likely to own cars than those in public rental housing [30]. In Beijing, longitudinal panel data revealed that relocation increased trip frequency and that changes in the social environment significantly affected travel behavior [31,32]. Forced relocation due to urban regeneration in Wuhan similarly altered commuting distances and neighborhood amenity access [33]. International comparisons from the United States further indicate that affordable housing residents exhibit lower vehicle trip rates than conventional models predict [34].

Shopping travel in Shanghai has been studied using survey data from the same period [35] found that 43.3% of residents walked as their primary shopping mode, highlighting a stark contrast with the low mobility documented in our peri-urban sample. Methodologically, a randomized experiment in Shanghai demonstrated causal effects of the built environment on travel behavior [36], and attitude-based market segmentation has been applied to low-income commuters in Fushun [37]. Mobile phone data have also been used to link residential segregation to travel mobility in Chinese cities [38]. International policy frameworks such as the 15-min city concept also highlight the importance of local accessibility [39].

2.3. Travel Behavior in Peri-Urban Areas of Developing Countries

Empirical research on peri-urban resettlement areas in developing-country megacities remains limited. Existing studies have largely focused on travel time, mode choice, or accessibility outcomes (see, e.g., [40] on mode choice), but few have systematically investigated trip generation rates and their determinants in policy-induced affordable housing peripheries. Recent work has begun to fill this gap. For example, ref. [24] examined the time-space behavior of affordable housing residents in Fuzhou, highlighting the role of perceived accessibility. A unique randomized experiment in Shanghai demonstrated causal effects of the built environment on travel behavior [36].

Moreover, studies from other developing countries highlight substantial gaps between objective and perceived accessibility in disadvantaged urban settings. For instance, research in informal communities in Ghana and Tanzania found that objective travel time underestimates perceived travel time by 133% in Kumasi and 50% in Dar es Salaam [41]. International studies from developed countries similarly confirm the importance of non-physical factors in shaping travel willingness among populations with mobility constraints [42]. However, these studies rarely integrate psychological constructs such as perceived behavioral control,

nor do they explicitly test elastic demand theory (see [11] for an empirical application) in relation to facility typology.

In India, quasi-longitudinal evidence from Hubli-Dharwad indicates that perceived neighborhood features independently affect vehicle ownership after relocation [43]. A study of short-term transnational relocation further demonstrates that residential self-selection and travel satisfaction interact to shape perceived accessibility [44]. From a methodological perspective, mixed-methods research in Santiago, Chile, reveals that perceived accessibility varies significantly by gender, age, and location, and that qualitative user experiences are often missed by quantitative indicators alone [45]. In the Netherlands, a large-scale study found that objective factors explain only 14.8% of the variance in perceived inaccessibility, underscoring the importance of unmeasured psychological and social factors [46]. Similar findings on the gap between calculated and perceived accessibility have been reported in rural-urban comparisons [47].

European panel data from Germany show that relocating to more urbanized areas reduces shopping distances, consistent with the logic that anchor facilities influence discretionary travel [48]. In Germany, latent class analysis of shopping behavior reveals substantial heterogeneity in mode and frequency choices, with some car-dependent groups also exhibiting high online shopping frequency [49]. These findings suggest that shopping travel patterns are shaped by a mix of attitudes, habits, and facility accessibility—a complexity that our facility awareness proxy only partially captures. Tulkowska-Słyk [50] identified accessibility to surrounding infrastructure as a key functional consideration in residential design, suggesting that spatial integration fundamentally shapes residents' ability to reach daily destinations.

We note that several of the studies cited above, including our own, were conducted using data collected before the widespread adoption of e-commerce and on-demand delivery in peri-urban areas. A growing body of literature documents that online shopping can substitute for physical trips, particularly for routine goods. For instance, ref. [51] found that 41.5–68.2% of respondents in Chengdu would increase their shopping travel frequency if daily necessities were unavailable online, indicating a strong substitution effect. Ref. [52] further demonstrated that e-shopping substitutes shopping trips across all travel modes (car, public transit, bicycle, walking), with daily goods (packaged foods, daily necessities) showing a particularly strong substitution effect on walking trips—the very mode most associated with accessing small-to-medium supermarkets. This substitution may fundamentally alter the relationship between facility awareness and travel frequency in contemporary contexts—a limitation we return to in Section 6.3, where we discuss the digital substitution caveat in detail.

2.4. Theoretical Framework: Heuristic Lenses, Not a Test

This study does not empirically test any formal theory. Instead, we use three theoretical strands as heuristic lenses to interpret our exploratory correlations and to generate testable hypotheses for future research.

2.4.1. Elastic Demand and the Type-Based Threshold Effect

Travel demand elasticity refers to how responsive trip rates are to changes in accessibility or cost. For routine, inelastic activities (e.g., buying basic food from a small supermarket), trip frequency is constrained by necessity and changes little with improved accessibility. For discretionary, elastic activities (e.g., shopping at a large mall), improved accessibility can substantially increase trip rates [11]. This implies a threshold effect: anchor facilities that offer variety, social interaction, and destination value are more likely to convert latent demand into actual trips, whereas small-to-medium routine facilities may not. Empirical

evidence from Beijing confirms that shopping trip demand becomes elastic only when retail density exceeds a critical threshold [53].

Our testable hypothesis—which we term a type-based threshold effect—is that awareness of a large shopping mall will be associated with higher shopping trip frequency. In contrast, awareness of small-to-medium supermarkets will show no such association. Critically, the effect is defined by facility category (anchor vs. routine) rather than by continuously measured distance or size alone—though distance and size may moderate the relationship. We caution that the elasticity of any given activity may vary across population subgroups and has likely been altered by the rise in e-commerce since 2012 (see Section 6.3).

2.4.2. Perceived Accessibility and the Theory of Planned Behavior (TPB) as Interpretive Lenses

Two additional constructs from the broader literature help frame our exploratory analysis. Perceived accessibility refers to an individual's subjective evaluation of how easily they can reach desired destinations [9]. The Theory of Planned Behavior highlights perceived behavioral control (PBC)—the belief in one's ability to perform a behavior—as a direct predictor of action. In resettlement contexts, even when objective infrastructure improves, residents' perceptions may lag, leading to continued low mobility.

A growing body of research has conceptualized and measured perceived accessibility. Ref. [54] provides a comprehensive theoretical framework distinguishing perceived from calculated accessibility, noting that perceived accessibility depends on spatial knowledge, individual capabilities, attitudes, and social context. A systematic literature review [55] concludes that objective indicators explain only a small portion of perceived accessibility variance and that definitions and measurements remain inconsistent. The updated accessibility model by [56] adds digital components and social interactions, directly supporting our argument that unmeasured psychological, social, and technological factors dominate travel decisions. The Special Issue introduction by [57] explicitly states that perceived accessibility can be regarded as a form of perceived behavioral control within TPB. Ref. [58] demonstrates empirically that perceived accessibility (as PBC) predicts intention to give up car ownership, while objective PTAL (a spatial network-based accessibility metric) does not. Similarly, ref. [59] found that perceived accessibility moderates the intention to switch to urban train services, further confirming the behavioral relevance of subjective accessibility perceptions.

Our empirical measure is a single-item, binary proxy: cognitive awareness of whether a large shopping mall exists near one's residence. This crude indicator captures at most one narrow facet of perceived accessibility or PBC. We do not claim to have measured these multidimensional constructs; we use them solely as heuristic lenses. Throughout this paper, we refer to our variable as 'facility awareness (of a large shopping mall)' to avoid overclaiming. Any interpretation invoking perceived accessibility or TPB is speculative and hypothesis-generating, not confirmatory.

2.4.3. Related Methodological and Empirical Studies on Perceived vs. Calculated Accessibility

Several studies have examined discrepancies between perceived and calculated accessibility. In Guangzhou, over 70% of spatial accessibility model outputs tested disagreed with residents' perceived park accessibility [60]. In Canada, perceived accessibility was found to differ systematically by income, education, and travel mode and to have stronger associations with travel satisfaction than objective indicators [61]. In the Netherlands, perceived accessibility is more evenly distributed than spatial accessibility, and residential self-selection reduces the urban-rural gap by 61.6% [62]. In Sweden, transport-related attitudes and habits were the strongest correlates of perceived accessibility across modes and trip purposes [63]. A study in Hungary extended perceived accessibility analysis to shared

micro-mobility modes [64]. Panel data from the Netherlands using cross-lagged models showed that travel behavior has a stronger effect on perceived accessibility than the reverse, highlighting the need for longitudinal designs to establish causality [65]. Acceptable travel distances also differ between urban and rural residents, with rural dwellers tolerating longer car trips but shorter public transport trips [66]. Using mobile signaling data from Shenzhen, Ref. [67] found that home-based non-commuting (HBNC) time positively influences relocation decisions, complementing our "relocation → travel" perspective with a reverse-causality lens.

In the Chinese context, ref. [68] demonstrated that space-time accessibility varies significantly by income, hukou, and housing type in suburban Guangzhou. Ref. [69] used the 2SFCA method to show that car ownership dramatically improves facility accessibility in Xiamen. Ref. [70] identified non-linear thresholds in the relationship between calculated accessibility and travel satisfaction in Tibet, methodologically analogous to our focus on threshold effects in facility awareness. Ref. [71] developed an equity evaluation framework combining calculated and perceived accessibility for affordable housing residents in Nanjing. Ref. [72] used Amap API data to quantify accessibility disparities by income group in Nanjing. Ref. [73] further validated the PAC (Perceived Accessibility Scale) scale and its sensitivity to service changes. Finally, using real-time travel data in Seoul, ref. [74] found that the effects of proximity to urban facilities on housing prices vary considerably by facility type, travel mode, and housing type—for instance, high-rise apartment prices are positively associated with proximity to high schools and healthcare, whereas low-rise multiunit commands higher prices when located further from schools but closer to parks—further demonstrating that facility typology can substantially shape the valuation of urban amenities. This finding reinforces the importance of distinguishing facility types in accessibility research. In Nanjing, affordable housing residents were found to have significantly lower perceived accessibility than commercial housing residents, reinforcing the importance of considering subjective perceptions in transport equity analyses [75].

2.4.4. Summary of Theoretical Positioning and Macro-Micro Integration

Summary of theoretical positioning. Our primary empirical contribution is to document correlations between facility awareness, trip frequency, and facility type in a unique 2012 baseline context. We interpret patterns consistent with elastic demand theory (threshold effects) as suggestive, and we tentatively relate them to broader ideas of perceived accessibility and PBC. From this exploratory analysis, we generate a core hypothesis for future research: facility awareness may be positively associated with shopping trip frequency, and this association may be mediated by perceived behavioral control (or perceived accessibility). This hypothesis is formalized as H1 in the future research agenda (Section 6.4.2).

To clarify the roles of these theoretical lenses, elastic demand theory operates at the macro level of facility typology, explaining why anchor facilities (large malls) are more likely than routine facilities (small supermarkets) to activate suppressed travel demand. The Theory of Planned Behavior and perceived accessibility operate at the micro level of individual cognition, explaining why residents' awareness of a facility—rather than its mere existence—influences their travel decisions. These two levels are complementary: the macro level explains which facilities matter, while the micro level explains why they matter for specific individuals. We do not claim that our single-item awareness measure captures the full multidimensional construct of perceived accessibility; rather, we use these frameworks as heuristic lenses to generate testable hypotheses for future research.

2.5. Research Gaps and Chapter Summary

This chapter summarizes how the study preliminarily addresses the research gap concerning the interaction among subjective cognition, facility typology, and travel frequency in peri-urban resettlement contexts. The study provides a rare baseline dataset from the early stage of policy-induced resettlement in Shanghai (2012), capturing mobility constraints before major infrastructure improvements. It identifies which factors are associated with low trip frequency—while transparently reporting that model R^2 values are very low (0.078 and 0.048), indicating that unmeasured psychological, social, and technological factors dominate. Further, it reports a correlational pattern in which awareness of a large shopping mall—but not of small-to-medium supermarkets—is associated with higher shopping trip frequency, consistent with a type-based threshold effect. Finally, it interprets these findings through heuristic lenses (elastic demand theory, perceived accessibility, TPB) in a hypothesis-generating manner, explicitly acknowledging that our single-item proxy does not measure multidimensional constructs, and calling for future research to employ validated scales and causal designs.

Given the exploratory nature of our results (low explained variance, cross-sectional design, 2012 baseline), we do not claim to inform current policy directly. Instead, we offer testable hypotheses (H1–H6) for future intervention studies. For example, whether mid-sized community hubs can produce a similar threshold effect in today's context, or whether perceived accessibility mediates the relationship between facility provision and trip frequency, should be re-evaluated with recent data and rigorous causal designs. Our primary contributions are theoretical (proposing and providing preliminary correlational support for a type-based threshold effect, distinguishing anchor vs. routine facilities) and methodological (the historical baseline itself).

3. Survey Site and Data

3.1. Survey Site

This paper concentrates on large-scale residential areas on the periphery of Shanghai. "Shanghai-periphery" refers to the area outside the Outer Ring Road (Figure 1), which is the boundary between the city center and the suburbs.



Figure 1. Locations of Case Areas on Shanghai City Periphery.

A "large-scale residential area" meets three criteria: covering approximately 5 km^2, having a population of approximately 100,000, and being composed primarily of affordable housing.

Shanghai is composed of 16 administrative districts. The survey sites are Jiangqiao, Gucun, Zhoukang, Pujiang, and Sijing—five large-scale residential areas (Figure 1) located in different districts. These sites were selected according to three criteria: high occupancy rate, predominantly affordable housing, and varied locations relative to Shanghai's central city (north, west, and south). The five case areas—Jiangqiao, Gucun, Zhoukang, Pujiang, and Sijing—were selected based on three criteria. First, they represent different geographic locations relative to Shanghai's central city (north, west, and south), ensuring variation in accessibility conditions. Second, they were all developed as part of Shanghai's large-scale affordable housing program during the same period, providing comparability in terms of policy context and development stage. Third, they had achieved high occupancy rates by the time of the survey, enabling sufficient sample sizes for statistical analysis. Gucun and Sijing were further selected for the detailed survey because they differ in character (Gucun exhibits urban sprawl, whereas Sijing does not) and are located in different directions, yet were at a similar stage of development. This selection allows us to capture the diversity of peri-urban resettlement experiences while maintaining analytical consistency. A field investigation of development conditions in the five areas was conducted to support site selection, on-site investigation, and interviews.

3.2. Sampling Approach and Survey Data

Because these areas were newly developed at the time of the survey, census data and other sources could not provide a useful sampling frame. Therefore, the research team conducted a field study of local transport conditions and facilities, a questionnaire survey, and interviews with residential committees and residents in the case areas in 2012. This survey captures a critical baseline period when these communities were in their initial formation stage, making the data uniquely valuable for understanding accessibility deficits and for future longitudinal comparisons. We use a single binary question—'Is there a large shopping mall near your living place (to your knowledge)?'—to capture facility awareness. As discussed in Section 2.4, we interpret associations between facility awareness and travel frequency as exploratory evidence consistent with the logic that perceived behavioral control or perceived accessibility may play a role, but this remains a hypothesis-generating interpretation, not a confirmatory test.

Sampling procedure. An in-house questionnaire survey was conducted under the guidance of residential committee staff and trained interviewers. Three sampling approaches were used: ① stratified sampling to select communities within each large-scale residential area; ② systematic sampling to select buildings within each community; and ③ random sampling to select households within each building. The objective of this multi-stage design was to ensure representativeness across geographic locations, housing types, and building positions within each of the five large-scale areas. For each selected household, interviewers guided residents aged six and above to complete a travel diary questionnaire, which collected information on family characteristics, personal attributes, one-day trips (the previous day), and travel-related issues.

Survey instruments and sample sizes. The survey included a travel diary and detailed questions on travel satisfaction and preferences. The travel diary was completed by 6037 households across the five large-scale residential areas, achieving a sampling rate of 1.6%. The detailed travel satisfaction and preference questionnaire was conducted only in two areas (Gucun and Sijing) and included 1034 respondents. Gucun and Sijing were selected from the five areas because: ① they differ in character (Gucun is close to the central

city and exhibits urban sprawl, whereas Sijing is far from the central city and has no sprawl character); ② they are located in different directions (Gucun in the north, Sijing in the south); and ③ they were at a similar stage of development.

After data cleansing, the travel diary has a valid sample size of 8390 residents. The detailed travel satisfaction, preference, and willingness questionnaire has a valid sample size of 1020 residents in Gucun and Sijing.

Temporal context and baseline value. Readers should note that the survey was conducted in 2012. This predates the widespread adoption of e-commerce and on-demand delivery in Shanghai's peri-urban areas—a limitation discussed in Section 6.4. Subsequent infrastructure improvements (e.g., the opening of Metro Line 13 in late 2012, new bus routes) have altered absolute travel frequencies. However, the relational patterns (i.e., which factors are associated with low mobility) offer insights for hypothesis generation and constitute our primary exploratory contribution. Readers should not assume these patterns are causal or directly transferable to today's Shanghai without further testing.

4. Maintenance Travel Frequency and Its Influential Factors

4.1. Travel Activity Classification and Research Focus

Residents' travel activities are commonly classified into three categories: subsistence (work/school), maintenance (shopping, errands, banking, healthcare), and leisure (dining, entertainment, social activities) [40,76]. Subsistence travel frequency is largely inflexible (e.g., fixed work schedules). Maintenance travel is necessary but flexible in frequency, while leisure travel is discretionary and also flexible.

This study focuses on maintenance travel, specifically shopping for necessities, as it is the most frequent maintenance activity [77] and offers policy-relevant flexibility. Leisure travel is not analyzed in this paper; readers should not infer any empirical findings about leisure travel from this study.

4.2. Descriptive Findings: Shopping Frequency and Rest-Day Destinations

In the detailed travel preference survey (Gucun and Sijing, N = 1020 valid residents), respondents reported shopping for necessities 2–3 times per week on average, meaning each shopping trip covered 2–3.5 days of needs (Figure 2).

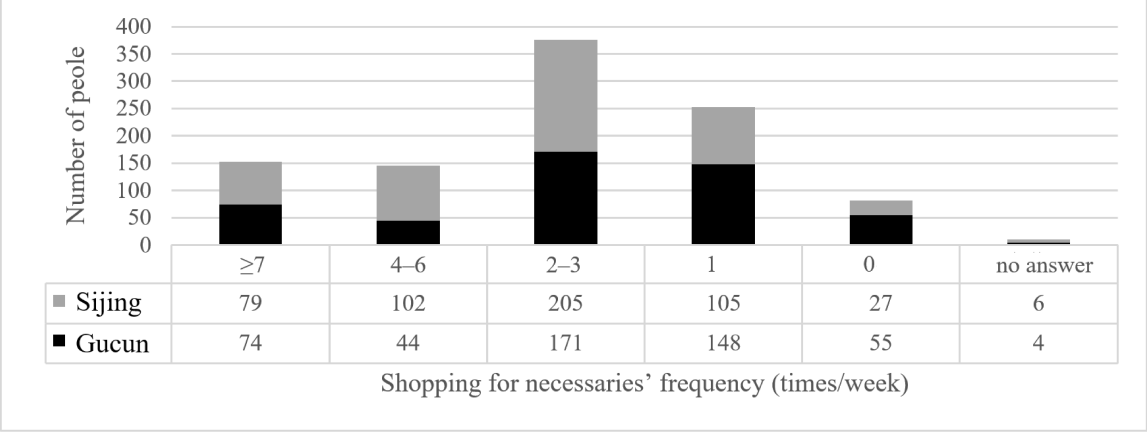


Figure 2. Shopping for Necessities' Frequency for Sijing and Gucun's 1020 valid resident samples (times/week).

Table 1 presents the most frequent rest-day activities and destinations. Shopping and resting at home are the top two rest-day activities. Importantly, over 60% of rest-day

destinations and 57% of shopping trip destinations are located close to residents' living locations rather than in central Shanghai (Table 1).

Table 1. Rest-Day Most-Common Activities and Most-Favored Travel Destinations.

	Most-Common Activities on Rest Days	No. of People	Most-Common Destinations on Rest Days	1st Choice	1st & 2nd Choice	Shopping Respondents
1	Shopping	713	Inside the central city (inside the middle ring road)	344	529	297
2	Dining and entertainment	268				
3	Art and sport	87	Non-central city, close to the living location (sum of the following three)	633	1245	405
4	Tourism	32				
5	Visiting friends and relatives	130				
6	Work overtime	23	Suburban sub-town	95	244	85
7	Pick-up or drop-off families	36	Near the community	249	534	278
8	See a doctor	22	Inside the community	289	467	42
9	Rest at home	682	Others	34	115	10
10	Others	39	Overall samples	1011	1889	712
Sample size: 1016 respondents; 4 people did not answer.		2032				

Note: When answering with the top 2 choices, the total number of people is the doubled sample size: 2032. The activity destinations of the 713 shopping respondents are shown on the very right (Among these shopping respondents, one did not answer this question, so 712 is the overall sample size).

Which factors are associated with shopping frequency, and which residents shop less frequently? The following subsections address these questions using logistic regression models—again noting upfront that, as with overall trip frequency, the model explains very little variance (R^2 = 0.048), indicating that unmeasured psychological, social, and technological factors dominate.

4.3. Logistic Regression Model Specification for Shopping Frequency

We estimated a binary logistic regression model; results are shown in Table 2.

Table 2. Results of the Binary Logistic Regression Model on the Low Frequency of Shopping for Necessities.

Category	Independent Variable's Name	Coeff. Est.	Sta. Err.	Wald	Sig. (*p*-Value)
Cognitive Environment and Satisfaction	1 Facility awareness: knows a large shopping mall near living place (exploratory proxy)	−0.332	0.147	5.077	0.024
	2 A middle- to small-sized supermarket near the living place	0.010	0.237	0.002	0.967
	3 A food market near the living place	0.249	0.167	2.223	0.136
	4 A store or shop near the living place	−0.162	0.157	1.057	0.304
	5 Satisfied with the facilities nearby	−0.136	0.207	0.432	0.511
	6 Dissatisfied with the facilities nearby	0.153	0.155	0.974	0.324
Demographic Characteristics	7 Gender—Male	0.275	0.140	3.842	0.050
	8 Education	0.206	0.059	12.295	0.000
	9 Car desire	−0.279	0.214	1.707	0.191
	10 Availability of a transport tool—Moped	−0.281	0.145	3.771	0.052
	11 Availability of a transport tool—Regular bike	−0.231	0.158	2.140	0.144
Constants	12 Constant	0.807	0.410	3.877	0.049

Table 2. *Cont.*

Category	Independent Variable's Name	Coeff. Est.	Sta. Err.	Wald	Sig. (*p*-Value)
	N = 1020 resident samples in Sijing and Gucun; Nagelkerke R^2: 0.048; −2 log likelihood: 880.953; Low shopping-for-necessities frequency of dummy 1: 711. Model Chi-square: 35.314. Degrees of freedom: 11, Sig.: 0.000 Dependent variable is the resident's shopping-for-necessities frequency dummy: y = 1 when the resident has a low frequency of shopping for necessities: 0–3 times per week; y = 0 when the resident has a high frequency of shopping for necessities: 4+ times per week.				
	40+ independent variables (as follows) were inputted and tried:				
	40+ independent variables inputted			Description	
1	Built environment indicators:				
	Location dummy			1 if the resident lives in Gucun, otherwise in Sijing 0	
	Living space dummy			1 if a 100+ m^2 apartment, otherwise 0	
	Parking dummy			1 if having a space in the community, otherwise 0	
2	Cognitive environment indicators:				
	(1) large shopping mall, (2) middle- to small-sized supermarket, (3) food market, (4) store and shop, (5) bank, and (6) post office			1 if there is such a facility in or near the residential area, otherwise 0	
3	Satisfaction towards facilities nearby			1 if satisfied, 0 if dissatisfied, 2 if neutral or no answer	
4	Transport service condition:				
	Public transport waiting time			Average, at home-side station, in minutes	
	Bus crowdedness			1 if there are seats, 2 no seats but not crowded, 3 crowded, and 4 overcrowded and hard to get on	
	Net public transport cost			On average in CNY/day, after deducting allowances	
	Parking fee dummy			1 if parking for free, otherwise 0	
5	Public transport satisfaction score:				
	Satisfaction full score 10 for the following 7 items: (1) service time, (2) frequency, (3) punctuality, (4) speed, (5) convenient transfer, (6) fare, (7) line and station layout				
6	Demographic characteristics:				
	(1) Regular: age, gender, permanent city residency, education, occupation (1 if worker, otherwise 0; or 1 if retired, otherwise 0), household average monthly income, household size (how many people)				
	(2) Job-housing characteristics:				
	Work location dummy			1 if working and living in the same district, otherwise 0	
	Relocatee dummy			1 if relocatee, otherwise 0	
	(3) Transportation characteristics:				
	Availability of 6 transport tools			1 if car, motorcycle, moped, fuel bike, e-bike, or regular bike is available, otherwise 0	
	Car desire			1 if planning to purchase a car, otherwise 0	
	Most often picked commute mode			1 if car, otherwise 0	
	Most often picked non-commute mode			1 if car, otherwise 0	

Dependent variable. A dummy variable representing shopping frequency for necessities:

$y = 1$ if the resident shops 0–3 times per week (low frequency);

$y = 0$ if the resident shops 4+ times per week (high frequency).

In Gucun, 24.6% of residents shopped 4+ times per week; in Sijing, 35.7% did so. Thus, most residents in our sample exhibit low shopping frequency.

Independent variables. The model included over 40 indicators covering built environment, cognitive environment (facility awareness), transport service, satisfaction with facilities and public transport, and demographic characteristics (full list below Table 2).

As foreshadowed in the Introduction and Section 4.2, this model explains very little variance (Nagelkerke R^2 = 0.048)—a finding that itself directs attention toward unmeasured psychological, social, and technological factors.

The constant term is statistically significant, which is routine when the baseline log-odds of the outcome are non-zero; we attach no substantive interpretation to it, consistent with the observation that most residents have low shopping frequency.

4.4. Model Results for Shopping Frequency

4.4.1. Cognitive Environment

Table 2 shows that residents who are aware of a large shopping mall near their living place have significantly higher shopping frequency for necessities (coefficient –0.332, $p = 0.024$). In contrast, awareness of small-to-medium supermarkets shows no significant association (coefficient 0.010, $p = 0.967$). This differential pattern—a type-based threshold effect—is consistent with elastic demand theory: shopping at a large mall is an elastic (discretionary) activity, for which improved accessibility may substantially increase trip rates, whereas routine grocery shopping is relatively inelastic. However, given the low explanatory power of our model (Nagelkerke $R^2 = 0.048$) and the cross-sectional design, causality cannot be inferred. The observed correlation is consistent with prior work showing that building retail closer to residences is associated with improved travel quality [7], but it does not establish a causal relationship.

4.4.2. Demographic Associations for Shopping Model

Table 2 reveals several demographic associations with shopping frequency. Male residents (coefficient 0.275, $p = 0.050$) and those with higher education (coefficient 0.206, $p < 0.001$) tend to have lower shopping frequency. Car desire shows a positive coefficient but does not reach conventional significance ($p = 0.191$). Moped availability is associated with higher shopping frequency (coefficient -0.281, $p = 0.052$), while regular bike availability shows a similar but non-significant trend (coefficient -0.231, $p = 0.144$). The stronger association for mopeds (compared to regular bikes) may reflect lower physical effort.

The observed demographic patterns are descriptive and should not be interpreted as causal. They may reflect gender roles, travel preferences, or unmeasured alternative channels (e.g., online shopping, not measured in our 2012 data). The association between private transport modes and higher shopping frequency warrants further investigation through causal research designs.

4.5. Effect Sizes and Model Limitations

For the shopping frequency model (Table 2), effect sizes are modest. Residents aware of a large shopping mall (coefficient -0.332, $p = 0.024$) have odds of low shopping frequency that are 0.72 times those of unaware residents ($OR = \exp(-0.332) = 0.72$). In probability terms, awareness reduces the predicted probability of low shopping frequency (shopping < 4 times/week) by approximately 4.3 percentage points (from about 70% to 66%). Moped availability (coefficient -0.281, $p = 0.052$) reduces the odds of low frequency by 24% ($OR = 0.76$), corresponding to a probability reduction of about 3.8 percentage points. Male residents (coefficient 0.275, $p = 0.050$) have 1.32 times higher odds of low frequency, a probability increase of about 3.5 percentage points.

These small marginal effects are consistent with the model's very low explanatory power (Nagelkerke $R^2 = 0.048$). They underscore that even statistically significant predictors have modest practical impacts and that unmeasured psychological, social, and technological factors dominate shopping frequency decisions.

*Hypothesis generation***.** The type-based threshold effect identified in Section 4.4.1—awareness of a large shopping mall, but not of small-to-medium supermarkets, is associated with higher shopping frequency—generates a testable hypothesis for future research: developing anchor facilities (e.g., large malls or, in today's context, mid-sized community hubs) near peri-urban resettlement areas may increase shopping trip frequency, but this requires causal confirmation via natural experiments or quasi-experimental designs. Similarly, the observed associations between private transport modes (mopeds, bikes) and higher shopping frequency warrant causal testing in future research.

4.6. Summary and Caveats

Leisure travel not analyzed. This study offers no empirical evidence on social exclusion related to discretionary activities. Future research should investigate leisure trip generation among vulnerable groups, as social exclusion may be particularly acute for non-essential activities.

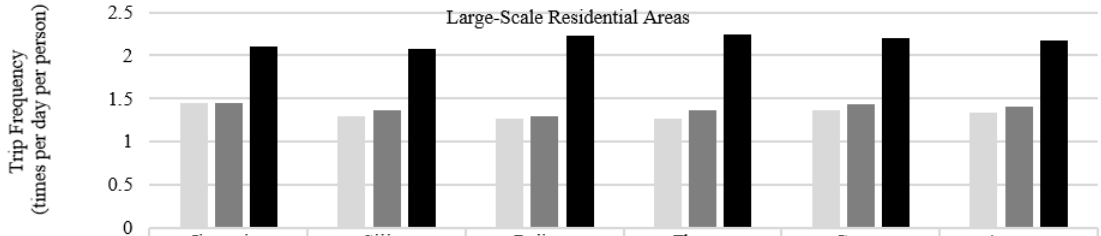
Reverse causality and cross-sectional design. The observed association between facility awareness and shopping frequency may reflect reverse causality: residents who shop more frequently may be more likely to learn about nearby facilities. Our cross-sectional design cannot disentangle this directionality. Therefore, the association should be interpreted as a correlation worthy of further testing—specifically, as a hypothesis-generating result for future longitudinal or quasi-experimental studies (e.g., before-after studies of new mall openings or information campaigns).

The following section examines overall trip frequency, complementing the core shopping-frequency analysis by testing whether similar vulnerability patterns hold for general mobility.

5. Travel Frequency and Its Influential Factors

5.1. Descriptive Findings and Limited Mobility

Travel frequency is measured as the average number of trips one person makes per day. Trip frequencies of the resident samples in the five large-scale residential areas were calculated using the travel diary questionnaire data, then weighted to the area population in 2010 (the closest detailed population census available). Results are shown in Figure 3.



	Jiangqiao	Sijing	Pujiang	Zhoupu	Gucun	Average
Sample	1.45	1.29	1.26	1.27	1.37	1.33
Weighted	1.45	1.37	1.29	1.36	1.43	1.4
District	2.11	2.08	2.23	2.25	2.2	2.17

Figure 3. Trip Frequency of (1) Resident Samples in Five Large-Scale Residential Areas, (2) Weighted to Area Population in 2010, and (3) the Districts in Which They Are Located.

In Figure 3, Gucun's trip frequency is 1.43 trips per day per person. Cellphone data from Gucun in 2011 show that residents had 1.25 travel destinations per day on average [78]—closely matching our survey result. Compared to the trip frequencies of the districts in which these areas are located and to the Shanghai citywide average of 2.23 trips/day [79], residents in the five large-scale residential areas have significantly lower trip frequency (Figure 3). The residents exhibit limited mobility. Given this limited mobility, the natural next questions are: what factors are associated with low trip frequency in these peri-urban areas, and which subgroups are most vulnerable? The following subsections address these questions using logistic regression models—while noting upfront that, as foreshadowed in the Introduction, these models explain very little variance (R^2 = 0.078), indicating that unmeasured psychological, social, and technological factors dominate.

5.2. Logistic Regression Model Specification for Overall Trip Frequency

We employed binary logistic regression rather than a count model (e.g., Poisson or negative binomial) for two reasons. First, our dependent variable—whether a resident made ≥3 trips on the diary day—is inherently binary, reflecting the 2012 Shanghai citywide average of 2.23 trips/day as a meaningful threshold. Second, the distribution of raw trip counts is highly skewed (mean = 1.43, median = 1; only 4.2% of the subsample made ≥3 trips), which poses estimation challenges for count models.

We estimated a binary logistic regression model. The dependent variable is a dummy for trip frequency:

$y = 1$ if the resident made ≥3 trips on the travel diary day (high frequency);

$y = 0$ if the resident made 0, 1, or 2 trips (low frequency).

In Gucun, only 5.44% of the resident samples made ≥3 trips on the diary day; in Sijing, only 3.05% did so. The independent variables included approximately 40 indicators covering demographic, built environment, cognitive, and transport service aspects (see full list below Table 3).

Table 3. Results of the Low-Trip-Frequency Binary Logistic Regression Model.

Category	Independent Variable's Name	Coeff. Est.	Sta. Err.	Wald	Sig.
Day Dummy	1 Rest Day	1.117	0.488	5.244	0.022
Built Environment	2 Location dummy—living in Gucun	−0.438	0.335	1.707	0.191
Demographic Characteristics	3 Most-often non-commute mode: car	−0.785	0.382	4.231	0.040
	4 Working and living in the same district	−0.664	0.325	4.165	0.041
	5 Car desire	−0.527	0.422	1.564	0.211
	6 Household average monthly income	−0.194	0.133	2.114	0.146
Constants	7 Constant	2.991	0.895	11.181	0.001
N = 1020 resident samples in Sijing and Gucun; High trip frequency dummy 1: 43; −2 log likelihood: 136.569; Nagelkerke R^2: 0.078; Model Chi-square: 23.708, Degrees of freedom: 6, Sig.: 0.001 Dependent variable is the resident trip frequency's dummy: y = 1 when the resident has a high trip frequency: traveled ≥3 times on the travel diary day; y = 0 when the resident has a low trip frequency: traveled 0, 1, or 2 times on the travel diary day. Forty independent variables (as follows) were included and tried. Only results of $p < 0.20$ are kept and shown above.					
	Forty Independent variables were input	Description			
1	Day dummy	1 if the travel diary day is a rest day, otherwise 0			
2	Built environment indicators:				
	Location dummy	1 if the resident lives in Gucun, otherwise in Sijing 0			
	Living space dummy	1 if 100+ m^2 apartment, otherwise 0			
	Parking dummy	1 if having a space in the community, otherwise 0			
3	Cognitive environment indicators:				
	For (1) large shopping mall, (2) middle- to small-sized supermarket, (3) food market, (4) store and shop, (5) bank, and (6) post office	1 if there is such a facility in or near the residential area, otherwise 0			
4	Satisfaction towards facilities nearby	1 if satisfied, 0 if dissatisfied, 2 if neutral or no answer			
5	Transport service condition:				
	Public transport waiting time	Average, at home-side station, in minutes			
	Bus crowdedness	1 if there are seats, 2 no seats but not crowded, 3 crowded, and 4 overcrowded and hard to get on			
	Net public transport cost	Average in CNY/day, after deducting allowances			
	Parking fee dummy	1 if parking for free, otherwise 0			
6	Public transport satisfaction score:				
	Satisfaction full score 10 for the following 7 items: (1) service time, (2) frequency, (3) punctuality, (4) speed, (5) convenient transfer, (6) fare, (7) line and station layout				

Table 3. *Cont.*

Category	Independent Variable's Name	Coeff. Est.	Sta. Err.	Wald	Sig.
7	Demographic characteristics:				
	(1) Regular: age, gender, permanent city residency, education, occupation (1 if worker, otherwise 0; or 1 if retired, otherwise 0), household average monthly income				
	(2) Job-housing characteristics:				
	Work location dummy	1 if working and living in the same district, otherwise 0			
	Relocatee dummy	1 if relocatee, otherwise 0			
	(3) Transportation characteristics:				
	Availability of 6 transport tools	1 if car, motorcycle, moped, fuel bike, e-bike, or regular bike available, otherwise 0			
	Car desire	1 if planning to purchase a car, otherwise 0			
	Most-often commute mode	1 if car, otherwise 0			
	Most-often non-commute mode	1 if car, otherwise 0			

Variable selection procedure. The cognitive environment indicators—which asked residents whether they were aware of the presence of various facility types (large shopping mall, medium-to-small supermarket, food market, store/shop, bank, post office) near their residence—follow the logic of self-reported spatial knowledge measures used in previous travel behavior research. For instance, Zhang et al. used hand-drawn 'familiar areas' as a mental map proxy and found that individuals' activity spaces were substantially nested within their self-reported familiar areas, validating the use of subjective spatial awareness indicators in travel analysis [80]. Our single-item binary indicators are a simpler, exploratory version of this general approach.

From the initial 40 candidate variables, we proceeded as follows: (1) We first entered all variables into a full binary logistic regression model. (2) We then used a backward stepwise elimination procedure based on the Akaike Information Criterion (AIC), with a removal threshold of $p > 0.20$ to retain potentially important variables given the exploratory nature of the study. (3) The final models presented in Table 3 (and Table 2 for shopping frequency) include only variables with $p < 0.20$ from this procedure. To avoid overfitting, we did not engage in further manual selection. The same procedure was applied to the shopping frequency model (Table 2).

The constant term is statistically significant but, as in Section 4.3, we attach no substantive interpretation to it. This matches the observation that most resident samples have low trip frequency (only 43 out of 1020 residents in the detailed subsample had high frequency).

5.3. Model Results for Overall Trip Frequency

5.3.1. Rest Day

Table 3 shows that on a rest day, residents have significantly lower odds of high trip frequency (coefficient 1.117, $p = 0.022$). Focus group discussions revealed that residents faced commutes of over one hour on overcrowded buses or metros during workdays, leading to fatigue. Consequently, on rest days they tended to rest at home rather than make additional trips—consistent with the model result.

Questionnaire analysis further shows that the two most frequent activities on rest days are shopping and resting at home. Among shopping trips, 57% of the most often visited destinations are not in central Shanghai but close to residents' living locations. Overall, over 60% of the most often destinations on rest days (first choice or top two choices) are located near their living areas rather than in the central city.

5.3.2. Built Environment

Table 3 indicates that residents in Gucun tend to have marginally higher trip frequency compared to those in Sijing (coefficient –0.438, $p = 0.191$), though this result does not

reach conventional statistical significance ($p < 0.05$). This marginal association may reflect Gucun's more developed facility conditions (transport, retail, etc.), as it is located in a central city sprawl area [7]. No other built environment variables showed significant associations.

Given the low explanatory power of our model (Nagelkerke $R^2 = 0.078$) and the cross-sectional design, we do not interpret this marginal finding as evidence of a causal effect. Instead, it suggests a testable hypothesis for future research: better facility conditions (e.g., mixed-use development, retail density) may be associated with higher trip frequency in peri-urban resettlement contexts.

Causal designs (e.g., natural experiments of new facility openings) are needed to test this hypothesis. The shopping frequency model (Section 4) reveals a clearer pattern regarding facility type.

5.3.3. Demographic Associations for Overall Model

Table 3 shows that residents whose most-often non-commute mode is a car and those whose workplace is in the same district as their residence are associated with higher trip frequency (coefficients -0.785, $p = 0.040$ and -0.664, $p = 0.041$, respectively). Car desire ($p = 0.191$) and higher household income ($p = 0.146$) show positive coefficients but do not reach conventional statistical significance. No other demographic variables yielded significant results.

If future causal research confirms that these factors are determinants rather than mere correlates, they could help identify vulnerable subgroups—e.g., residents without car access, with long cross-district commutes, no car purchase intention, or lower income. For now, we offer these as descriptive vulnerability profiles for hypothesis generation, not as actionable policy targets.

5.4. Robustness Checks and Effect Sizes

Robustness checks on the trip frequency threshold. The choice of $\geq$3 trips/day as the threshold for 'high' frequency was based on two considerations. First, the 2012 Shanghai citywide average was 2.23 trips/day; setting the threshold above the average identifies residents who are notably more active than the norm. Second, only 4.2% of our subsample met this criterion, isolating a clearly distinct minority. Nevertheless, using a higher threshold reduces statistical power and may contribute to the low R^2. Future studies with larger samples of highly active residents should validate our findings.

Interpretation of effect sizes (odds ratios and marginal effects). For significant predictors in Table 3:

- A rest day (coefficient 1.117, $p = 0.022$) increases the odds of low trip frequency by a factor of 3.06 (OR = exp (1.117) = 3.06). The marginal effect is an increase in the probability of low frequency by approximately 8.5 percentage points (from a baseline predicted probability of about 4% for high frequency).
- Residents whose most-often non-commute mode is a car (coefficient -0.785, $p = 0.040$) have 54% lower odds of low trip frequency ($OR = 0.46$). The marginal effect is a reduction in the probability of low frequency by about 2.1 percentage points.

These effect sizes, while statistically detectable, are modest—consistent with the low overall R^2. Given that the baseline probability of high trip frequency was only 4.2% in our subsample, the absolute change in probability associated with a rest day, for example, was from 96% low-frequency probability to 98.5%. These modest effect sizes further underscore that unmeasured factors dominate travel frequency decisions.

6. Discussion

6.1. Summary of Findings

Our analysis confirms a limited mobility condition among peri-urban resettlement residents (e.g., Gucun: 1.43 trips/day vs. Shanghai average: 2.23 trips/day). The core finding is a type-based threshold effect: awareness of a large shopping mall is associated with higher shopping trip frequency (coefficient –0.332, $p = 0.024$), whereas awareness of small-to-medium supermarkets shows no significant association.

6.2. Implications for Sustainable and Inclusive Mobility in the Built Environment

The findings of this study offer insights into the interplay between built environment design, mobility behavior, and social equity. These are central concerns of the sustainable mobility agenda. Given the exploratory nature of our findings (low R^2, cross-sectional design, 2012 baseline), the following implications are hypothesis-generating, not prescriptive. They are offered to stimulate future intervention studies, not to guide immediate policy action. Readers should re-evaluate any implications with recent data and causal designs before application.

6.2.1. Facility Awareness as an Exploratory Proxy for Perceived Accessibility (Theoretical Hypothesis)

Limited mobility in our sample is associated with poor facility awareness—a crude proxy for one narrow facet of perceived accessibility. Residents unaware of a nearby large shopping mall exhibited significantly lower shopping trip frequencies (coefficient –0.332, $p = 0.024$, Table 2), controlling for transport availability and demographics. This pattern suggests that subjective evaluations of destination accessibility may be a bottleneck, even when objective infrastructure exists.

Using the Theory of Planned Behavior as a heuristic lens, facility awareness may approximate perceived behavioral control (PBC)—the belief in one's ability to perform a behavior. Residents who believe destinations are difficult to reach (low PBC) may make fewer trips, regardless of objective access. This interpretation is speculative and hypothesis-generating.

This suggests a mediation hypothesis: facility awareness may be positively associated with shopping trip frequency, with perceived behavioral control (or perceived accessibility) potentially mediating this relationship. We formalize this as H1 in Section 6.4.2.

A key insight for future research: perceived accessibility can lag behind objective accessibility, especially in newly developed resettlement areas. Bridging the accessibility gap may require not only physical infrastructure but also mechanisms to enhance perceived behavioral control among marginalized populations—a hypothesis for direct testing.

6.2.2. Elastic Demand and Facility Typology (Threshold Effect Hypothesis)

Our core correlational finding—large shopping malls associated with higher shopping frequency, small-to-medium supermarkets not—is consistent with a type-based threshold effect. Under elastic demand theory, discretionary (elastic) activities respond more to improved accessibility than routine (inelastic) activities. This challenges the assumption that any retail facility equally improves mobility.

As a tentative hypothesis for future testing, we propose a dual-tier facility distinction observed in our 2012 context:

Tier 1 (inelastic, routine): Small supermarkets and food markets—necessary for basic needs but not associated with increased mobility.

Tier 2 (elastic, discretionary): Large shopping malls—associated with higher shopping trip frequency.

For contemporary contexts, we hypothesize that mid-sized community hubs (e.g., 5000–10,000 m^2 with mixed retail, services, and social spaces) may produce a similar threshold effect. Future quasi-experimental studies should compare trip frequency changes before and after the opening of different facility types to test this hypothesis. This speculative interpretation is consistent with Wojnowska-Heciak et al. [42], who found that non-physical attributes—such as social interaction opportunities and place attractiveness—are as important as physical accessibility in motivating travel among mobility-impaired populations.

A balanced perspective on sustainable mobility also requires acknowledging that increased accessibility may generate externalities such as environmental noise [81] and micromobility comfort limitations.

We caution that the observed threshold effect is correlational, not causal. The cross-sectional design cannot rule out reverse causality (more frequent shoppers may be more likely to learn about nearby malls) or unmeasured confounding. Therefore, we interpret the threshold effect as a hypothesis-generating finding that requires confirmation through longitudinal or quasi-experimental designs (e.g., before-after studies of new mall openings).

Recent studies on contemporary mobility patterns have highlighted the transformative role of digital platforms and shared mobility services in reshaping travel behavior [36,51,52]. While our 2012 baseline limits direct comparability of trip frequency estimates, the core theoretical contribution—the type-based threshold effect—may persist even as mobility modes evolve. For instance, ride-hailing services may function as 'anchor' mobility options that activate suppressed travel demand, whereas fixed-route public transport may serve as 'routine' services.

6.2.3. Vulnerability Profiles and Testable Hypotheses (Social Equity)

Our descriptive models identify several subgroups with lower trip frequency, suggesting potential vulnerability profiles (not causal determinants): residents whose most common non-commute mode is not a car (captive public transport users or walkers), those who work outside their home district (long commutes, time poverty), those with no car purchase intention, those with lower household income, and male residents and those with higher education (who shop for necessities less frequently).

These profiles indicate a double disadvantage: living farther from opportunities and lacking private mobility tools (cars, mopeds) that could compensate. Infrastructure improvements (e.g., new metro lines) may disproportionately benefit already advantaged groups unless accompanied by targeted interventions. This risk is not merely hypothetical: empirical evidence from the same metropolitan region shows that after a new shopping plaza opened, the travel equity gap between relocatees and non-relocatees widened measurably, with the consumer surplus difference increasing from −2.67 CNY to −5.72 CNY per shopping trip [28].

Based on these exploratory patterns, we offer five testable hypotheses (H2–H6) concerning shared mobility, information interventions, employer-based policies, equity monitoring, and digital substitution moderation. These are elaborated in Section 6.4.2 along with H1 (perceived accessibility mediation) and are not recommended for direct policy implementation without causal validation.

We do not recommend direct policy implementation based solely on these exploratory results. Rigorous intervention studies (e.g., natural experiments, RCTs) are needed first to establish causality. Gawell et al. [82] offer an international precedent, demonstrating that sustainable mobility infrastructure can embed universal access and inclusion as core design principles—a direction worthy of testing in peri-urban resettlement contexts.

6.2.4. Policy Resonance: Threshold Effects and the "15-Min Community Life Circle"

Our core finding—that large mall awareness, but not small-supermarket awareness, is associated with higher shopping frequency—offers a historical baseline note to Shanghai's current "15-Min Community Life Circle" initiative [83]. The 2023 Action Plan [83] promotes "one-stop comprehensive service centers" as community anchors, emphasizing mixed use and social interaction over mere spatial proximity.

This resonates with the type-based threshold effect we observed: only facilities that crossed an attractiveness threshold were associated with increased mobility. This suggests a testable hypothesis for contemporary planning—facility type and attractiveness could be at least as important as sheer density or distance in activating suppressed travel demand in resource-scarce resettlement areas—though this requires empirical verification with contemporary data. The "1 + N" spatial model in the Action Plan, where smaller nodes complement a central hub, aligns with this logic.

However, this implication is correlational and historical (2012, pre-e-commerce). Digital substitution [51,52] may have altered the relationship, and what constitutes an "anchor" today requires re-evaluation with current data. A tentative takeaway for future research is that facility typology and perceived attractiveness may be important, yet under-researched, levers for improving accessibility in peri-urban resettlement contexts—a proposition meriting rigorous testing with contemporary data and causal designs.

This finding resonates with broader international efforts—such as the New European Bauhaus and the 15-Min City concept—that seek to integrate sustainability, inclusion, and quality of experience in urban mobility infrastructure [82].

However, as with any mobility intervention, these strategies should be implemented with awareness of potential trade-offs. Sustainable mobility policies should also account for negative externalities—for instance, pavement quality and tire type can significantly affect rider comfort and vehicle reliability in micromobility systems [84,85].

Practical implications for planning and policy. Our findings, while exploratory, suggest three actionable directions for future intervention research. First, the type-based threshold effect implies that facility typology matters: planners should prioritize anchor facilities (e.g., mixed-use community hubs) over routine small supermarkets when aiming to activate suppressed travel demand in peri-urban resettlement areas. Second, the significant association between facility awareness and trip frequency suggests that information-based interventions—such as community notice boards or WeChat updates—could improve perceived accessibility at low cost. Third, the vulnerability profiles identified (carless, low-income, long-distance commuters) point to the need for targeted mobility interventions, including subsidized shared mobility programs and employer-based flexible work arrangements. However, these implications require verification through causal research designs before implementation.

Summary. Bridging the accessibility gap in peri-urban resettlement may require a dual hypothesis for future testing: (a) improving physical infrastructure—especially anchor facilities that cross an attractiveness threshold—and (b) strengthening residents' perceived behavioral control through targeted information, mobility subsidies, or community-based programs. Without the second component, infrastructure investments risk reinforcing existing inequalities.

6.3. Data Timeliness and Baseline Value

The 2012 data collection year is critical to understanding this study's contribution. At that time, the five surveyed large-scale residential areas were newly established, with underdeveloped transport infrastructure (e.g., no metro station near Jiangqiao, infrequent bus ser-

vices, few retail anchors). This represents a transient but methodologically valuable baseline snapshot—capturing mobility limitations before subsequent infrastructure improvements.

Subsequent years brought substantial changes: Metro Line 13 opened in late 2012, community bus routes were added, and large shopping malls were constructed [86–89]. Policy documents have since promoted 15-min community life circles to improve local accessibility [83]. The research on elderly metro travel in Nanjing [90] further highlights the importance of considering vulnerable groups in accessibility planning—a lesson that applies beyond the elderly to resettled populations more broadly.

The 2012 data therefore provide a rare empirical anchor for:

Longitudinal comparisons—future studies can measure how much of the mobility gap has been closed by specific interventions.

Mechanism identification—the mechanisms we identify (e.g., the role of perceived accessibility and threshold effect) are theoretically plausible and can be tested in other contexts, even as absolute trip frequencies change.

The temporal context is particularly valuable for developing-country cities currently undergoing rapid urbanization and facing similar peri-urban resettlement pressures [36]. Our survey methodology, analytical approach, and key findings (especially the facility threshold effect) are transferable to those contexts, even if specific numeric trip rates are not.

Digital substitution caveat.

Our 2012 data predate the widespread adoption of e-commerce and on-demand delivery in China's peri-urban areas. At that time, residents had few alternatives to physical shopping trips. Today, platforms such as Pinduoduo and Meituan Select enable online grocery ordering with delivery to community points, while food delivery and on-demand courier services (e.g., Meituan, Ele.me, and its evolved brand Taobao Flash Buy) allow residents to obtain prepared meals, groceries, daily necessities, and even electronics within 30 min without leaving home. These services, taken together, likely attenuate—or fundamentally alter—the relationship between physical facility awareness and shopping trip frequency.

This transformation has profound implications for the generalizability of our findings. We identify two competing hypotheses for how e-commerce may reshape this relationship. The substitution hypothesis posits that online platforms reduce the need for physical shopping trips, thereby attenuating the association between facility awareness and shopping frequency. Residents unaware of a nearby large mall may now meet routine shopping needs online, reducing the "limited mobility" penalty observed in our 2012 data. The complementary hypothesis, in contrast, suggests that e-commerce may enhance rather than replace physical shopping by creating online-to-offline (O2O) synergies. For example, discovering products online may prompt visits to physical stores for inspection, fitting, or immediate purchase. A third, mode-specific possibility is that online shopping substitutes for routine goods (packaged foods, daily necessities) but complements experiential shopping (clothing, entertainment), which may still require physical visits. Current evidence suggests that the substitution effect dominates for routine goods, particularly for walking trips—the very mode most associated with accessing small-to-medium supermarkets [51,52].

Residents unaware of a nearby mall may now meet routine needs through these platforms, reducing the observed "limited mobility" penalty. Conversely, facility awareness may remain important for discretionary, experiential shopping less easily substituted online. However, the net effect on the facility awareness–trip frequency relationship remains unclear and may vary across population subgroups—for instance, by age, digital literacy, or income—as well as by trip purpose. For older residents or those with limited digital skills, the substitution effect may be weaker, and physical facility awareness may remain a stronger predictor of shopping frequency. Future research should explicitly measure

e-commerce behavior alongside physical trip frequency and test whether online shopping mediates or moderates this relationship—and whether the substitution or complementary effect dominates in different segments of the resettled population.

Our findings are therefore specific to a pre-e-commerce era. The theoretical mechanisms—the threshold effect, the anchor-vs-routine distinction, and the role of cognitive awareness—remain valid for hypothesis generation. However, absolute effect sizes and any implied facility prescriptions require re-evaluation with contemporary data that account for digital substitution.

The preceding discussion suggests a testable proposition: the substitution effect may dominate for routine goods, whereas the complementary effect may prevail for experiential shopping, with the net effect likely varying across population subgroups (e.g., by age, digital literacy, or income). We formalize this as H6 (Digital substitution moderation) in the future research agenda (Section 6.4.2).

Transferable insight. For contemporary applications, the key insight is not the specific facility type (large mall) but the threshold principle: elastic activities require anchor destinations that exceed a certain attractiveness level. What constitutes an 'anchor' in today's context (e.g., integrated community centers with retail, services, and social spaces) and what distance or size thresholds apply are open questions for future natural experiments.

6.4. Limitations and Future Research Agenda

6.4.1. Limitations

This study has several limitations, organized into four thematic groups.

Causal interpretability. All associations are correlational. Reverse causality is possible: residents who shop more frequently may be more likely to learn about nearby malls. Residential self-selection, though weakened by policy-induced allocation, may still introduce bias. We did not perform E-value sensitivity analysis; readers should treat the facility awareness–shopping frequency association as potentially sensitive to unmeasured confounding.

Measurement and operationalization. Our facility awareness measure is a single binary indicator—a crude proxy for one narrow facet of perceived accessibility or perceived behavioral control. It conflates information gaps, travel distance, transport quality, social networks, and cognitive maps. We do not claim equivalence to validated scales. The cross-sectional design (2012 only) prevents observation of adaptation over time. The models' very low explanatory power ($R^2 = 0.078$; 0.048) indicates that unmeasured psychological (attitudes, PBC), social (networks, norms), and technological (e-commerce) factors dominate travel decisions. Missing variables likely include direct TPB constructs, social network variables, online shopping behavior, and detailed activity space data. Micro-scale physical environmental features—including pavement quality, street tree presence, and walkable surface design—may independently shape pedestrian comfort and route quality, factors not captured in our models [91–93]. These low Nagelkerke R^2 values raise an important question: which unmeasured variables most likely account for the unexplained variance? We identify three categories of missing variables. First, psychological constructs directly drawn from TPB—attitudes toward travel, subjective norms, and perceived behavioral control (PBC)—were not measured in our 2012 survey. Second, social network variables—frequency of visiting friends/family, caregiving responsibilities, and neighborhood social cohesion—likely shape travel decisions but were not captured. Third, technological substitution variables—particularly online shopping and tele-activities—were minimal in 2012 but are now dominant. Our data predate the widespread adoption of e-commerce, meaning we could not measure the extent to which residents substituted

physical shopping trips with online alternatives. Future research should explicitly measure these missing dimensions to achieve higher explanatory power.

Generalizability and temporal relevance. Absolute trip frequencies (e.g., 1.43 trips/day in Gucun) are specific to Shanghai's 2012 context and should not be directly compared across cities or time periods. However, relational patterns (e.g., threshold effects) are likely more generalizable. The rapid proliferation of food delivery and on-demand courier services (e.g., Meituan, Ele.me/Taobao Flash Buy) since the mid-2010s has provided residents with alternatives to physical shopping that did not exist in 2012. Leisure travel was not analyzed; future research should investigate discretionary trip generation among vulnerable groups.

Other methodological constraints. The $\geq$3 trips/day threshold for 'high' frequency identified only 4.2% of the subsample as highly active, reducing statistical power—though sensitivity analyses confirmed the main findings were robust to alternative thresholds. Sensitivity analyses using alternative thresholds and Poisson regression yielded consistent results, but count data models are preferred for future work. Self-reported travel diaries are subject to recall and social desirability bias. Future survey platforms should move toward passive, machine-learning-enhanced data collection that captures both in-person and online activities, building on recent precedents such as the smartphone-based travel and activity diary [94] and the integrated vehicle-and-shipment tracking system for freight surveys [95]. A 'Smart Mobility and Activity Responsive Tracker or Survey Platform' adapted for peri-urban resettlement contexts could yield more accurate data on facility awareness and travel behavior.

Looking beyond measurement, emerging mobility technologies—such as the Sunglider system assessed by Gawell et al. [82]—illustrate that future transport solutions can embed accessibility as a design priority, an open question for peri-urban resettlement contexts. Autonomous vehicles, whose adoption is shaped by psychological factors such as trait mindfulness [96] and whose subscription-based models have demonstrated measurable willingness to pay among car-oriented populations [97], could, if made accessible to car-deprived peri-urban residents, fundamentally alter the accessibility constraints identified in this study. Whether AVs would complement or substitute for physical proximity to anchor facilities remains an open question for future research.

Finally, any implied facility prescriptions based on 2012 conditions (e.g., large malls) require re-evaluation with contemporary data; the threshold effect logic—that elastic activities require attractive anchor destinations—remains valid, but the specific facility type and size thresholds are open questions.

6.4.2. Future Research Agenda

Based on these limitations, we propose the following priorities for future work: ① longitudinal panel studies tracking changes in perceived accessibility, travel frequency, and social participation alongside infrastructure investments; ② comparative studies across developing-country megacities (e.g., Mumbai, São Paulo, Lagos, Jakarta) to test the generalizability of threshold effects and the role of perceived accessibility; ③ integration of passive mobility data (mobile phone traces, smart card records) with household surveys for higher temporal and spatial resolution; ④ randomized or quasi-experimental evaluations of specific interventions (new bus routes, mall openings, information campaigns) on perceived behavioral control and trip frequency, with equity-disaggregated outcomes; and ⑤ qualitative and mixed-methods studies to unpack why some residents remain unaware of nearby facilities and what barriers prevent low-income, carless residents from forming accurate perceptions.

The following hypotheses emerge from our exploratory findings and are offered to guide future research:

H1 (Perceived accessibility mediation). *Facility awareness may be positively associated with shopping frequency, mediated by perceived behavioral control. Test using validated TPB and PAC scales*.

H2 (Shared mobility). *Subsidized access to shared e-scooters/e-bikes for carless, low-income households may increase maintenance trip frequency (e.g., ≥0.3 trips/day). Test via randomized or quasi-experimental designs*.

H3 (Information intervention). *Low-cost community information campaigns about nearby anchor facilities may increase shopping frequency among unaware subgroups. Test via controlled before-after studies*.

H4 (Employer-based intervention). *Flexible working hours or employer-provided shuttle buses for residents working outside their home district may increase non-work trip frequency. Quasi-experimental evaluations recommended*.

H5 (Equity monitoring). *Post-occupancy evaluations with validated perceived accessibility scales could reveal whether infrastructure investments narrow or widen mobility gaps across income, car ownership, and employment subgroups. Longitudinal designs encouraged*.

H6 (Digital substitution moderation). *E-commerce use moderates the relationship between facility awareness and shopping trip frequency. Test whether the substitution effect (for routine goods) or the complementary effect (for experiential shopping) dominates across different population subgroups, using surveys that capture both online shopping behavior and physical trip frequency*.

The primary value of this 2012 baseline is to generate these testable propositions—not to provide ready-to-implement policy solutions.

7. Conclusions

7.1. Contributions

We make four contributions.

The first contribution is theoretical. We introduce and provide preliminary correlational support for a type-based threshold effect—distinguishing anchor facilities (large malls) from routine facilities (small supermarkets) in their association with travel frequency. Using the Theory of Planned Behavior and perceived accessibility as heuristic lenses, we generate the hypothesis that facility awareness may proxy for perceived behavioral control, a proposition requiring direct testing with validated scales.

The second contribution is empirical. We provide a rare large-scale baseline dataset from the critical early stage of policy-induced resettlement in Shanghai (2012), when infrastructure gaps were most pronounced. This baseline enables future longitudinal comparisons and mechanism identification.

The third contribution is methodological. The 2012 travel diary data serve as an empirical anchor for future quasi-experimental and longitudinal research. Researchers can use this baseline to measure how subsequent infrastructure investments (metro extensions, community bus routes, anchor retail openings) have altered mobility patterns and accessibility gaps over time.

The fourth contribution is hypothesis generation. From our exploratory findings, we articulate six testable hypotheses (H1–H6) concerning perceived accessibility mediation, shared mobility interventions, information campaigns, employer-based policies, equity monitoring, and digital substitution moderation—offering a roadmap for future causal research.

Planning and design implications. The findings offer three hypothesis-generating directions for future planning research rather than immediate policy prescriptions. First, the type-based threshold effect suggests that facility typology matters: anchor facilities may activate suppressed demand more effectively than routine small supermarkets. Second, the facility-awareness association implies that low-cost information interventions may enhance perceived accessibility. Third, the vulnerability profiles point to the need for targeted mobility programs. These directions are elaborated in Section 6.2.4 and require empirical verification through causal designs (e.g., natural experiments and quasi-experiments) before implementation.

7.2. Generalizability and Hypothesis Transfer

Our operationalization of perceived accessibility is limited to a single-item awareness measure. Readers should interpret findings related to perceived accessibility as preliminary and hypothesis-generating. The top priority for future research is replication using validated multidimensional scales (e.g., PAC Scale, full TPB instruments).

The mechanisms we identify—especially the type-based threshold effect and the role of facility awareness—are theoretically generalizable to other rapidly urbanizing contexts where policy-induced resettlement creates similar early-stage infrastructure gaps. However, absolute trip frequencies (e.g., 1.43 trips/day) should not be directly compared across cities or time periods without contextual adjustment.

For cities currently undergoing early-stage resettlement, our findings offer the testable hypothesis that prioritizing anchor facilities may be associated with higher trip frequency—a hypothesis requiring testing with local data and causal designs. For established megacities like contemporary Shanghai, the findings inform theory more than direct practice; any application should be preceded by replication studies using recent data that account for e-commerce substitution. For contexts where e-commerce is prevalent, the role of physical facility awareness may be attenuated for routine goods but remain relevant for experiential shopping.

Overall, by linking facility awareness, built environment characteristics, and mobility outcomes, this study contributes to the interdisciplinary knowledge base required for designing sustainable and inclusive cities—a core mission of the sustainable mobility and built environment agenda.

7.3. Limitations and Outlook

This study has several limitations (detailed in Section 6.4): cross-sectional design, single-item awareness proxy, low model explanatory power, exclusion of leisure travel, and 2012 data that predate widespread e-commerce. These limitations do not invalidate our findings but define their scope as exploratory and hypothesis-generating.

Future research should prioritize: (a) longitudinal panel studies tracking perceived accessibility and travel frequency alongside infrastructure investments; (b) comparative studies across developing country megacities; (c) integration of passive mobility data; (d) randomized or quasi-experimental evaluations of specific interventions (e.g., information campaigns, shared mobility subsidies); and (e) qualitative studies unpacking barriers to facility awareness among vulnerable groups.

For future research, we propose that longitudinal and quasi-experimental studies should test whether prioritizing communities with high concentrations of vulnerable groups in '15-min life circle' initiatives can effectively improve mobility outcomes. Similarly, we recommend that future studies investigate whether monitoring changes in perceived accessibility among these groups should be a standard component of post-occupancy

evaluation rather than implementing such policies directly. Our findings offer testable hypotheses for intervention research, not immediate policy prescriptions.

We do not recommend direct policy implementation based solely on these exploratory results. Rigorous intervention studies are needed first to establish causality. The core mechanisms we identify—threshold effects, the role of cognitive awareness, and the likely dominance of psychological and social factors—offer a useful starting point for future longitudinal, comparative, and intervention-focused research in peri-urban resettlement contexts worldwide.

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