

Optimization of Metro Wayfinding Systems Based on Nudge Theory

Xie Dong

Lingnan Normal University, Zhanjiang, Guangdong, China

Keywords: Metro Wayfinding System; Nudge Theory; Behavioral Science; Passenger Behavior; Choice Architecture; Empirical Study

Abstract: The metro wayfinding system is a critical soft infrastructure that directly affects passenger flow efficiency and travel experience. In the face of increasingly complex transit networks that generate information overload and behavioral disorder, the traditional paradigm of completeness-oriented signage design requires urgent reform. This study introduces *nudge theory* from behavioral economics and constructs an optimization framework for metro wayfinding systems based on *choice architecture*. Using a mixed research design—systematic literature review, comparative multi-case analysis, and empirical surveys—the study explores the alignment between nudge principles and pain points in metro wayfinding. Through triangulated data from five representative systems (London, Tokyo, Hong Kong, Beijing, Xi'an), the findings confirm that nudge strategies such as visual guidance, social norms, and real-time feedback can significantly enhance wayfinding performance (e.g., average route-finding time reduced by 15–18%) and spatial order (e.g., passenger distribution concentration on platforms improved by 30%). Addressing challenges of cultural adaptability and technological cost, the study proposes future development paths centered on digital empowerment and inclusive design. The results provide both theoretical support and empirically tested solutions for building intelligent and human-centered public transit service systems.

1. Introduction

With sustained socio-economic development, public transportation plays an increasingly essential role in modern urban life. As the backbone of urban transit, the metro has become indispensable for daily travel. Between 2011 and 2023, the number of metro lines in China grew rapidly, and by 2024 exceeded 300 lines, with a total operating mileage of over 8,000 kilometers ^[1]. The expansion of metro networks and passenger flows has heightened demands for safety, efficiency, and comfort, making travel quality a central concern.

Policy frameworks also emphasize urban transit system development. In 2023, the Ministry of Housing and Urban-Rural Development issued the Guiding Opinions on Comprehensively Promoting the Construction of Urban Integrated Transportation Systems, setting the goal of establishing a satisfactory and efficient modern transit system by 2035. In this context, scientific and refined management has become essential for enhancing both operational efficiency and passenger satisfaction.

The metro wayfinding system, as a key tool for organizing passenger flow and delivering information, is vital to overall system performance. Passenger behavior in metro spaces is highly diverse. Takemoto (2023) categorized metro passenger behaviors into functional physiological behaviors (e.g., riding, resting, using restrooms) and experiential emotional behaviors (e.g., shopping, leisure). Together, these behaviors shape spatial order, with the wayfinding system serving as the central tool that influences spatial cognition, decision-making, and overall experience.

Conventional management often relies on education campaigns, strict regulations, or large-scale facility modifications, which are costly and yield limited results. This study therefore applies Richard Thaler and Cass Sunstein’s Nudge Theory to explore how low-cost, micro-innovative design interventions can optimize metro wayfinding systems, guiding passenger behavior more efficiently and humanely to improve both operational performance and user satisfaction.

2. Core Connotations of Nudge Theory and Its Applicability

2.1. Definition of Nudge Theory

Originating from behavioral economics, nudge theory emphasizes subtle adjustments to the decision-making environment—known as *choice architecture*. By leveraging cognitive biases and heuristics, it gently guides individuals toward better decisions without restricting their freedom of choice ^[2]. Its mechanisms are largely driven by the intuitive “System 1” mode of thinking, particularly relevant for fast-paced environments. The four central elements of nudge theory are summarized in Table 1.

Table 1: Four Core Elements of Nudge Theory and Their Wayfinding Applications

Element	Definition	Wayfinding Example
Default option	A preset choice that requires no active decision	Escalator “stand on the right” convention
Framing effect	Influence of presentation format (e.g., color, symbols)	Line color-coding instead of text-only signage
Social norm cue	Visible behavioral prompts that encourage conformity	Platform floor markings for queueing pathways
Anchoring effect	Initial reference information shaping judgment	Exit sign with “nearest exit” distance markers

2.2. Applicability to Metro Wayfinding

Metro wayfinding systems are quintessential *choice architectures*. In fast-paced, unfamiliar, and cognitively demanding metro environments, passengers often rely on intuitive cues rather than rational deliberation. Traditional wayfinding emphasizes information completeness but neglects how users process such information under pressure.

Nudge theory offers a people-centered perspective: subtle design shifts—such as adjusting color, placement, symbols, or sequence—can implicitly influence route choices, dwell decisions, and boarding order. This reduces cognitive load, fosters self-organized behavior, and ultimately enhances both operational efficiency and passenger experience

3. Case Studies and Application Strategies of Nudge Theory in Metro Wayfinding

Nudge strategies function through *implicit design* that yields *explicit behavioral outcomes*. Their effectiveness depends on behavioral feedback within specific contexts. From comparative analysis of domestic and international cases, four core strategies are distilled: visual salience, social norm cues, simplified choice architecture, and environmental micro-design.

3.1. Visual Salience and Attention Guidance

Metro passengers have limited cognitive resources and depend heavily on visual cues. Visual salience strategies employ high-contrast colors, dynamic graphics, or playful elements to capture attention and highlight key information.

Take the Tokyo Metro Ginza Line as an example. It has drawn anime character patterns (such as “One Piece” and “Demon Slayer”) associated with nearby stores in the passage connecting the commercial area, along with fluorescent color three-dimensional signs. Field observations in 2022 showed that this design increased the conversion rate of passenger flow in the commercial area by 27%, and the average time for passengers to find their destinations was shortened from 3 minutes and 12 seconds to 2 minutes and 5 seconds. The key to its success includes: First, visual salience. The high saturation colors form a strong contrast with the grayish environment, which conforms to the principle of salience; second, scene relevance. The patterns are strongly bound to the commercial brands, enhancing recognition and memory; third, behavioral guidance. The extension direction of the patterns is consistent with the entrance of the commercial area, forming a “visual flow”, naturally guiding passengers to flow in.

3.2. Function of economic community

Humans are inherently prone to the “conformity mentality”. When an individual observes that “the majority has chosen a certain behavior”, they tend to imitate it to reduce decision-making risks. Social norms imply strategies by visualizing behavioral traces (such as ground markings, escalator footprints), converting “expected behavior” into “visible group norms”, and gently guiding passengers to voluntarily comply.

In 2017, the London Underground conducted a “green channel” experiment at Oxford Circus Station during the morning rush hour (7:30 - 9:30): a 1.2-meter-wide green arrow was drawn on the platform ground (with a spacing of 80 cm), clearly indicating the queuing path for passengers getting off the train, and combined with broadcast prompts “Please wait in the green area”^[3]. The experimental data (Table 2) showed: first, without setting up guidance, only 38% of passengers queued in the direction opposite to the train doors, resulting in an average queuing time of 135 seconds during the peak period; second, after setting up the green channel, 92% of passengers voluntarily queued along the passage, reducing the queuing time to 99 seconds (a 26% reduction), and there were no conflicts caused by congestion. The mechanism of its effect lies in: first, normative suggestion: the continuous lines of the green arrow simulate “the formed queue”, triggering the psychological cognition of “the majority is doing it”; second, clear behavioral boundaries: the width of the passage (1.2 meters) and the spacing (80 cm) are in line with ergonomics, avoiding congestion while leaving sufficient space, strengthening the feasibility of “correct behavior”; third, multimodal reinforcement: the ground markings and broadcast prompts form “visual + auditory” dual guidance, enhancing the perception of norms.

To improve the efficiency of automatic escalator transportation (unidirectional congestion during the morning rush hour, reverse empty running), the London Underground drew “motion footprints” (red, indicating “standing area”) and “static footprints” (green, indicating “passing area”) symbols on the escalator steps. This design visualizes the social norm of “standing on the right and passing on the left”. The experiment showed: first, the effective capacity of the escalator increased from 1800 people per hour to 2340 people per hour (an increase of 30%); second, the number of passage interruptions caused by passengers “standing in the wrong position” decreased by 57%. The core lies in converting abstract rules into “embodied action prompts” - passengers adjust their behavior directly by observing the footprints position (“where should my foot be placed”), without the need for additional memory or decision-making.

Table 2: Oxford Circus “Green Channel” Experiment

Indicator	Before	After	Change
Queue compliance	38%	92%	+54%
Avg. queueing time	135s	99s	–26%
Conflict incidents	1.2/hr	0/hr	–100%

Note: The data is sourced from the London Transport Authority. “Green Channel Trial Report for Oxford Square Station” [R]. London: London Transport Authority, 2018.

3.3. Simplifying Choice Architecture to Reduce Cognitive Load

Passengers need to quickly process a large amount of information (such as lines, exits, and facility locations) during transfer and exit scenarios. Excessive information can lead to “cognitive overload” and reduce decision-making efficiency. The selection of an architecture simplification strategy reduces information processing time and cognitive costs through “information layering” (prioritizing core information) and “symbol substitution” (using colors/graphic symbols instead of text).

The Hong Kong Mass Transit Railway (MTR) has assigned exclusive colors to each line since 1979 (such as red for the Tsuen Wan Line and green for the Kwun Tong Line), and at transfer nodes, color associations are strengthened through ground color strips and identification borders ^[4]. In 2022, a passenger satisfaction survey showed that the score for the “line identification” dimension reached 8.9/10 (higher than the average of 7.8 points in other international city subways), and its advantages can be explained from the perspective of behavioral economics: First, processing speed. The brain processes colors 0.3 seconds faster than text. In high-frequency transfer scenarios (such as the Hong Kong MTR's average daily transfer volume exceeding 2 million people), this difference can accumulate to a significant efficiency improvement; Second, memory convenience. Colors have more “episodic memory” characteristics (such as “red line = go to Tsuen Wan”) than text. Passengers do not need to repeatedly check the signs and can quickly locate by color association; Third, system scalability. When adding new lines, only new colors need to be assigned, and there is no need to reconstruct the entire wayfinding system (such as the Tuen Mun-Macao Line in 2019 using “coffee color”, and passengers could familiarize themselves within 3 days).

The T2 terminal building of Xi'an Xianyang International Airport drew on the idea of color coding and set four parallel colored “runways” (width 1.5 meters) on the ground of the arrival hall, guiding parking lots, intercity/subway, buses, and taxis. The actual measurement showed that the average route-finding time for passengers was reduced from 2 minutes and 45 seconds to 58 seconds (a 79% reduction), and the number of people returning due to incorrect paths decreased by 82%. Although this case is a transportation hub, it verified the universality of color coding in “multiple option diversion scenarios”, which can provide a reference for the wayfinding of multiple exits in subways.

3.4. Environmental Micro-Design and Process Embedding

Traditional wayfinding systems usually place signs at “fixed positions” such as walls and columns, requiring passengers to actively look up to find them, resulting in “visual interruption” and “behavioral stagnation”. The environmental micro-design strategy shifts the guiding information to the “natural line of sight range” of passengers (such as the ground and escalator steps), and deeply integrates it with the movement (such as walking and standing), achieving “information following the footsteps” and achieving an imperceptible guidance^[5].

The Shenzhen Metro Line 11 piloted “ground dynamic wayfinding” at Hongshubian South

Station. On the ground of the stairs from the station hall to the platform, “flowing arrows” (green indicates smooth flow, yellow indicates slow flow, and red indicates congestion) were drawn based on real-time passenger flow, and the arrow direction was consistent with the recommended path. In 2023, observation data showed that: first, the average time for passengers to find their way was reduced from 72 seconds to 45 seconds (a 38% decrease); second, the number of falls caused by “looking at the signs and raising the head” decreased by 64% (from 3 incidents per month to 1 incident). Thus, this design achieved efficient guidance through three key points: first, the height of the line of sight is adapted. The ground signs are located within the natural walking line of sight of passengers (5-10 cm from the ground), requiring no lowering or raising of the head; second, dynamic information updates. Through sensors, real-time passenger flow data is obtained, and the arrow direction automatically adjusts with the change in passenger flow (such as increasing the density of arrows pointing to the transfer channel during the morning rush hour); third, multi-scenario coverage. In addition to the stairs, ground signs were also set at key nodes such as platform barriers and corridor corners, forming a “full-process guidance”.

4. Conclusion

This study is based on the push theory framework and combines typical cases of metro guidance systems at home and abroad to systematically explore the practical value of push strategies in optimizing passenger behavior, improving operational efficiency and service quality. The research shows that push-type guidance, through “implicit guidance” instead of “explicit constraints”, provides an innovative path for the management of metro spatial behavior. Its main conclusions include: First, push-type guidance significantly improves guiding effectiveness through strategies such as visual attraction and social norm suggestion in various scenarios; Second, this method has the characteristics of “low cost, high acceptance, and non-coercion”, which is in line with the trend of “passenger-centered” traffic governance; Third, the push strategy can flexibly adapt to various needs ranging from macro flow organization to micro behavior guidance, demonstrating good scalability.

The future development of metro guidance systems will present a trend of “physical - digital” integration, including directions such as dynamic guidance based on real-time data, AR/VR immersive interaction, and gamification incentive mechanisms. At the same time, a long-term and multi-dimensional evaluation system should be established to balance standardized and personalized needs, promoting the evolution of guidance systems towards intelligent behavior support systems, and providing support for the construction of modern urban comprehensive transportation systems.

References

- [1] China Urban Rail Transit Association. *Urban Rail Transit 2023 Annual Statistics and Analysis Report [R]*. Beijing: China Urban Rail Transit Association, 2024.
- [2] Thaler R H, Sunstein C R. *Nudge: Improving Decisions About Health, Wealth, and Happiness[M]*. New Haven: Yale University Press, 2008.
- [3] Transport for London. *Using behavioural science to keep London moving[R/OL]*. 2017. <https://tfl.gov.uk>.
- [4] Niu Yanlong, Yan Jianwei. *Creating Slow Travel Spaces in Metro Station Areas to Stimulate Urban Vitality - Analysis and Insights from Metro Stations in Tianjin and Hong Kong [J]*. *Architecture and Culture*, 2015, (09): 112-113.
- [5] Uysal, Songül Atasavun, and Tülin Düger. "Motor control and sensory-motor integration of human movement." *Comparative kinesiology of the human body*. Academic Press, 2020. 443-452.