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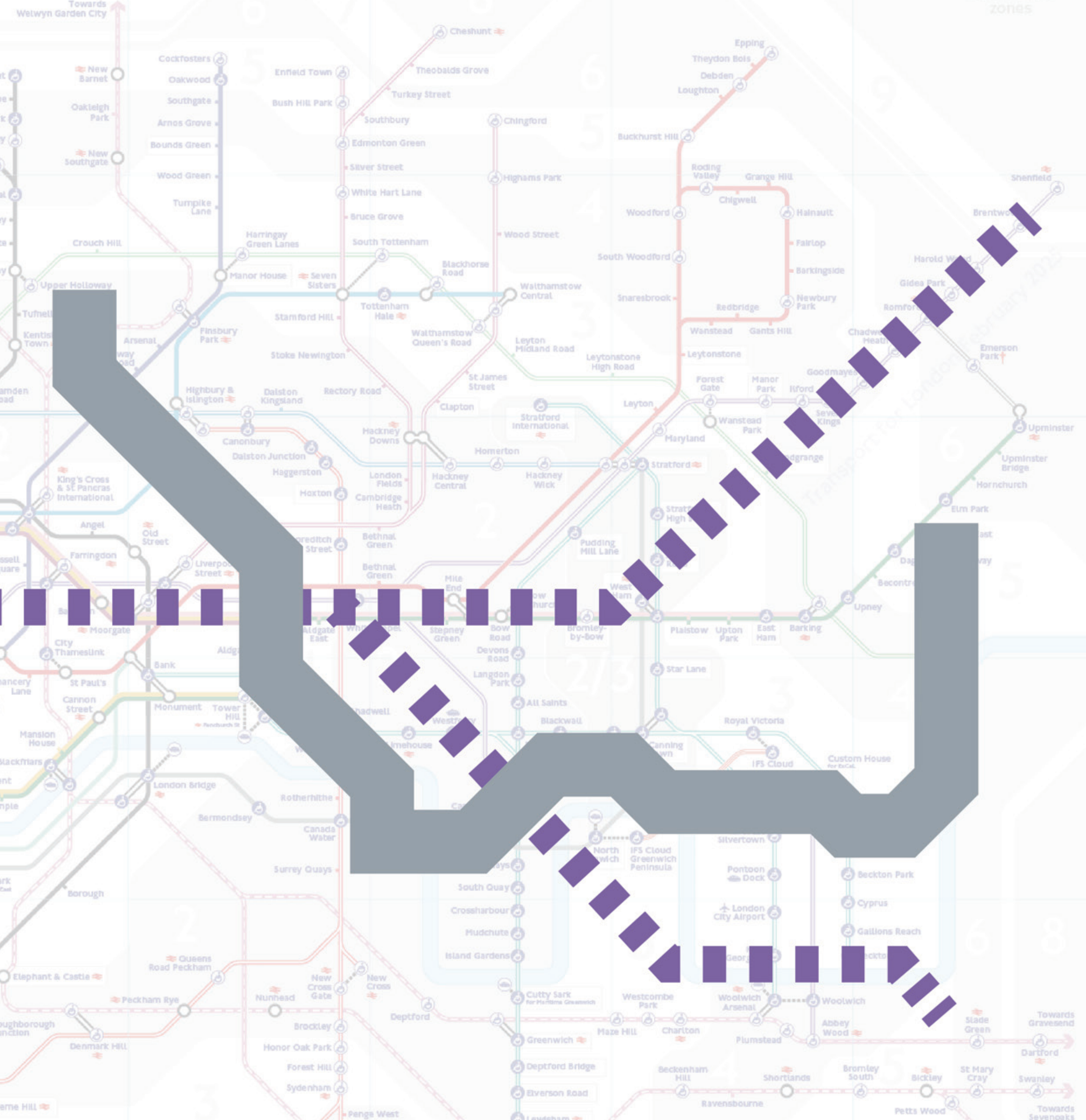

MEASURE TIME BARRIERS IN LONDON UNDERGROUND

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Content

To my grandmother——Xiuzhen Yuan

At the beginning of this journey,
I owe my deepest gratitude to my
grandmother.
For twenty-five years,
I walked beside her wheels—
and watched how each step of the world
seemed built to resist her.

She once told me:
"Going out is always a hassle."
Not because she lacked the will,
but because the world lacked the welcome.

'You do not belong here.'

I began this research
so that people like her
no longer feel that movement
is a burden they must justify.

Everyone deserves to move
without apology,
to live without hesitation.

And this,
is what I hope to contribute.

Acknowledges

I would like to express my sincere gratitude to my supervisors for their invaluable guidance, critical insights, and continuous support throughout the development of this research. Special thanks to the accessibility users and disability advocates whose experiences and perspectives inspired the design and evaluation of this study. I also appreciate the feedback and resources provided by Transport for London (TfL), which made the mapping and simulation processes possible. Finally, I am grateful to my friends and family for their encouragement and patience during the entire research journey.

Abstract

This thesis critically investigates how Transport for London (TfL)'s accessible infrastructure, while nominally step-free, produces temporal exclusion for wheelchair users through a set of overlooked design and management logics. Drawing on phenomenology, crip theory, and time-geography, this research introduces the concept of the "time barrier"—a form of infrastructural inequality embedded not in spatial inaccessibility alone, but in time-related delays, detours, and disruptions encountered in everyday urban mobility. The study using mapping and simulating journey to answer the questions. After After nine simulated trips on the Elizabeth and Jubilee lines, the findings reveal three dominant forms of time barriers: delay-based, detour-based, and blockage-based, which are not accounted for in TfL's current design standards or policy evaluations. A critical policy analysis of TfL's 2024 accessibility documents further demonstrates a systemic absence of temporal performance as an evaluative metric. This thesis proposes "time as infrastructure" as a new policy framework for rethinking accessibility beyond the physical, arguing for the integration of embodied temporal experience into infrastructure design, maintenance, and assessment. The study contributes both a methodological model for mapping time-based accessibility and a normative intervention into the governance of urban mobility infrastructures.

Chapter 1: Introduction

> ***Step-free' access means lifts, ramps and level surfaces so you do not have to use stairs or escalators, and can avoid the step and gap onto our trains, buses and boats.***
>
> ***— Transport for London (Accessed on 19 May 2025)***

In modern cities, mobility is necessary for autonomous and independent living and for achieving fair and equal participation in society (Levin et al., 2012; Mackett,2020). For a metropolitan area like London, mobility equality has always been a key concern for urban transport. However, for wheelchair users, equality of mobility is often challenged. In London, for example, the Underground system carries around 3 million people per day, although the Disability Discrimination Act was passed after 1995 to amend the policy on accessibility. According to the TFL report (Transport for London, 2025), by March 2025, 92 of the 270 stations on the London Underground will have step-free access from the platform to the train. In reality, however, wheelchair users face a complex travelling experience, with complicated transfer systems, out-of-service or congested lifts, and a lack of clearly signposted spaces. This suggests that wheelchair users in London continue to experience mobility difficulties in terms of urban mobility.

This mobility dilemma is related to TFL's accessibility assessment criteria.

TfL defines "accessibility" as physical infrastructure configuration — including lifts, ramps, low-floor trains, and accessible ticket gates (Transport for London, 2024). Figure 1 shows photographs of these physical accessibility infrastructures inside London Underground stations.

In this framework, the 'presence' of accessibility facilities becomes the leading indicator for measuring how accessible the infrastructure is. However, this planning logic, which centres on spatial accessibility, ignores the time delays experienced by wheelchair users in actual journeys and passengers' experiences within the underground system (Velho, 2017) as noted in a 2023 report by TFL, wheelchair users in London spend, on average, five times longer commuting on the Underground than non-disabled passengers. (Transport for all, 2023). This phenomenon reveals that accessibility should not be assessed solely based on physical coverage. Time and experiential narratives should also be considered as factors influencing accessible travel.

Figure 1: Accessibility infrastructure of the London Underground. Source: photo by the author.

Existing academic research on transport accessibility reveals similar limitations. Much of the literature focuses on the physical layout and distribution of accessibility features, such as the number and coverage of ramps, lifts, and guidance systems (Sze, N.N. and Christensen, K.M., 2017; Gamache, S. et al., 2019; Ripat, J. and Colatruglio; A., 2015). While these studies highlight the impact of physical infrastructure coverage on disabled people's travel, there is a general lack of analysis of disabled people's travel experiences. As Velho, R. points out, there is a significant gap between accessibility facilities and their availability in everyday use, especially for wheelchair users. Similarly, research by Hidayati, I., Yamu, C., and Tan, W. (2020) also suggests that not all individuals have similar levels of mobility to engage with so-called accessible infrastructure. Together, these studies critique the logic of narratives based on physical accessibility infrastructure. Therefore, this study proposes an approach to evaluating accessibility infrastructure through a narrative lens focused on time and lived experience.

It is necessary to explain why I chose wheelchair users as the primary focus of my study. The mobility of wheelchair users is deeply linked with the structural design of the urban public transport systems (Velho, R. 2017). Their journeys rely heavily on physical infrastructure, such as lifts and ramps, and are most spatially and temporally constrained in the urban transport system. The accessibility and availability of these facilities directly determine whether wheelchair users can arrive at their destinations on time. From a personal perspective, my decision is also shaped by lived experience. My grandmother has been a wheelchair user for 25 years, and through my close relationship with her, I have come to deeply understand the role that infrastructure plays in shaping her mobility. For example, on 24th August 2023, when we travelled by train in China, she could not move through the train carriage due to the lack of a suitable accessible passage. She had no choice but to remain seated at the junction between two carriages. Compared to other disabled groups, wheelchair users are more dependent on physical infrastructure to support their mobility (Velho, R. 2017). At the same time, a review of TFL's official policies and related reports shows that wheelchair users are the most frequently included category within their defined "target user groups" for accessibility. TFL's accessibility standards are often judged by being "step-free from street to platform or train" to determine whether a station is accessible to wheelchair users. Based on this, this research focuses on wheelchair users, aiming to examine the structural issues in urban transport accessibility infrastructure where the temporal and experiential dimensions are systematically neglected.

This study introduces the concept of the time barrier as its central analytical framework by examining the behaviours, patterns, and conditions of wheelchair users within the underground system.

Time Barrier means the additional time burden experienced by wheelchair users during their journeys, caused by factors such as limited infrastructure capacity, insufficient management arrangements, or failures in information systems. This includes long waiting times, routing detours, unusual movement interruptions, and delayed arrivals. In contrast to traditional accessibility evaluations, Time Barrier offers a framework grounded in temporal and experiential analysis. It centres on the forms of mobility exclusion that wheelchair users encounter over time. Therefore, time barriers will be used as the key analytical framework throughout this study's methodology, findings, and discussion.

Further, this study proposes a policy suggestion— Time as infrastructure, which argues for the inclusion of time in the system of accessibility infrastructure construction and management.

Through embedding temporal considerations into TFL 's official policies—including management, measurement and system optimisation- the aim is to reduce, and ideally avoid time barriers, thereby improving the accessibility of urban transport systems across both spatial and temporal levels.

Specifically, this research is structured around discussing three sub-questions:

1. Do wheelchair users experience significant time barriers during underground travel? If so, at which stages of the journey do these barriers primarily occur?

2. How are these time barriers related to the design and management logic of the transport infrastructure?

3. How might temporal performance be used as a new criterion for evaluating the usefulness of accessibility infrastructure?

To address the above questions, this study adopts phenomenology and Crip Time theory as its methodological foundation. The structure of the thesis is as follows:

Chapter 2 reviews the relevant theoretical and methodological literature on accessibility infrastructure, time, disability studies, transport, Time geography and Crip theory;

Chapter 3 introduces this study's methodological framework, focusing on two primary approaches: mapping and simulated travel. It also addresses the details of the research design and ethical considerations.

Chapter 4 summarises the whole process of the simulated travel and presents key findings. It also summarises and categorises the time barrier phenomenon encountered during the simulated travel and discusses it.

Chapter 5 will discuss TFL's current accessibility policies on accessibility and how Temporal performance can be incorporated into infrastructure evaluation criteria.

Chapter 6 summarises the main findings of this study.

Chapter 2: Literature review

As mentioned in the introduction, this paper aims to build an alternative narrative framework centred on 'time' to challenge traditional accessibility narratives and to demonstrate the invisible temporal exclusion experienced by wheelchair users in the underground system.

To achieve this aim, examining the existing academic research is first necessary.

This chapter offers a systematic literature review across four key areas:

1. Discussions on the accessibility and temporality of the underground as a form of public transport infrastructure;

2. The contributions and limitations of Disability Studies in analysing transport systems;

3. Methodological insights from Time-Geography for infrastructure analysis;

4. Theoretical developments in Crip Theory and Crip Time.

This study reviews four strands of literature to highlight a key gap in current research on accessible urban transport and social mobility: the lack of attention to issues of temporal justice. This gap builds the theoretical foundation for the research methods used in this study.

2.1 Transport Infrastructure, Accessibility, and Temporal Gaps in Urban Transport

'Infrastructure' first appeared as "the basic physical and organisational structures required for modernisation processes (Gandy, M. 2011, p. 58). Infrastructure studies have explored vertical and horizontal spatial dimensions and accessibility, visibility, disruption, and spatial fragmentation (Gandy, M. 2011; Graham, S. 2010; Graham, S. and Marvin, S. 2001; Appel, H. et al., 2015). These works aim to explore the impact of material structure on modern society. Furthermore, the concept of infrastructure extends to being a social organisation that influences city power relations (Graham, S. and Marvin, S., 2001). Within this framework, infrastructure is not only a material product but also shapes the power dynamics between cities.

In infrastructure research, Star, S.L. and Ruhleder, K. (1996) emphasise that the value of infrastructure should not be measured solely by its physical form, but rather by whether it is used, accessible, and trusted. The 'presence' of infrastructure is not the same as 'accessibility'; it serves different social groups unevenly and reflects biases in its spatial distribution. From this perspective, accessibility infrastructure in urban transport systems carries significant research value. It exposes the gap between physical infrastructure provision and physical accessibility, especially for marginalised users such wheelchair users.

As mentioned in the Introduction, TfL's current evaluation standards for accessibility primarily rely on the coverage of physical infrastructure. Similarly, much of the existing academic literature on transport accessibility reflects this limitation. A large body of literature focuses on the spatial layout and distribution of accessible facilities. Imrie, R. (1996) and Luis, A. et al. (2022) argue that the physical conditions of urban transport systems - such as accessibility of accessible routes, lifts, tactile paving and guide signs- are decisive for the inclusion or exclusion of disabled users. In addition, the number of installations and coverage of ramps, lifts, and guidance systems are also used as indicators to evaluate accessibility (Sze, N.N. and Christensen, K.M., 2017; Gamache, S. et al., 2019; Ripat, J. and Colatruglio; A., 2015).

These studies effectively demonstrated the importance of physical infrastructure coverage for disabled people's mobility, but there is a general lack of analysis of disabled people's travel experiences. As Velho, R. (2017) highlights, there is a significant gap between accessible infrastructure and its availability, especially in the daily practice of wheelchair users. The research by Hidayati,I., Yamu,C. and Tan,W. (2020) also suggests that not all individuals have similar levels of mobility to adapt to the accessibility infrastructure. Collectively, these studies critique the logic of narratives based on physical accessibility infrastructure.

However, more scholars are now focusing on alternative dimensions, beyond physical infrastructure. For instance, Bissell, D. (2018), in his study on commuting, emphasises how temporal changes during commuting are perceived through different bodily experiences, and how people reflect on their relationships with time in everyday life. Jensen, O.B. (2013) argues that infrastructure should be understood as a mobilities assemblage, organised through patterns of perception and embodied practices. Rhythm, sensory experience, and bodily states are emerging as new conceptual entry points in infrastructure research. Within their framework of rhythmanalysis, Bissell, D. and Fuller, G.(2011) point out that different urban bodies experience infrastructural rhythms in varied ways—through stay, delay, and dislocation—producing unequal rhythmic experiences.

Although scholars in infrastructure and disability studies have begun to focus on issues such as urban rhythms, delays and time experiences, time has still not been systematically incorporated into infrastructure assessment and design criteria in studying urban transport accessibility systems. This research introduces the analytical framework of the Time Barrier. It seeks to expose the mechanisms of temporal exclusion behind seemingly "accessible" systems.

Through a focused case study of London's underground system (TfL), the study argues that even on lines with relatively high step-free coverage, wheelchair users continue to face frequent instances of waiting, missed connections, and disruptions to their travel. Collectively, these experiences constitute a Time Barrier that is institutionally overlooked.

2.2 *Disability studies and transport system critique*

Disability Studies, as an interdisciplinary field, has developed through a theoretical trajectory that moves from the Medical Model to the Social Model, and more recently towards Critical Disability Studies (CDS). The Medical Model views disability as a physical impairment that needs to be 'corrected' through treatment and rehabilitation. The Social Model, on the other hand, is fundamentally different. The social model fundamentally overturns this perspective, arguing that the social environment constructs disability, and that structural exclusion in society leads to the exclusion of disabled people (Oliver, M. 1990). In this framework, barriers are defined as products of structural social exclusion.

Futher, Critical Disability Studies(CDS) develops the view that disability is not only a matter of social structure, but is more deeply related to how cultural norms, technologies of power, and mechanisms of governance define 'normalcy' and 'deviation' (Goodley, D. et al., 2019; Titchkosky, T. 2024).

Disability research has significantly influenced the' construction and critical evaluation of urban transport systems. For instance, TFL claims it supports the social model of disability, which upholds the view that a disabled person's environment, rather than their body, limits their ability to complete a task (Transport for London, 2018).

Within disability-led narratives of accessibility, removing barriers has become a key objective in designing and implementing accessible infrastructures. However, this process of transforming infrastructure by 'removing barriers' has begun to reveal its limitations. Harblay, C. (2017) critically analyses how physical infrastructure can be overdetermined as 'good' or 'bad', and suggests that disabled people can act as 'expert users' in shaping accessible environments.

However, although there are still limitations to the impact of disability research on urban transport planning, some scholars have begun to explore the temporal and experiential dimensions of using accessibility infrastructure. Stock, R. (2022) argues that wheelchair users' travel experiences are often affected by "temporal disruptions" in urban public transport systems, particularly delays caused by the failure of key facilities such as lifts. These interruptions disrupt travel rhythms and lead users to engage in new forms of knowledge production, such as social media protest and digital mapping. Such interruptions caused by lift failures sometimes result in unplanned detours for wheelchair users. They can lead to 'temporary breakdowns' (Jackson, S.J., 2017, p.183) and a limited range of movement (Müggenburg, J., 2021). These studies have shown that the time and experience of disabled people in infrastructure systems have become a new direction for research. These studies provide a strong theoretical foundation for this research's introduction of 'temporal narratives' into the analysis of underground accessibility infrastructure. Building on this foundation, this thesis continues in the tradition of Critical Disability Studies, highlighting how the management and design logic of accessibility infrastructure generates Time Barriers that fundamentally shape the travel experiences of wheelchair users.

2.3 Methodological insights from Time-Geography for infrastructure analysis;

Hägerstrand's theory of time geography has been widely applied in accessibility studies and has gradually evolved into a general analytical framework (Patterson, Z. and Farber, S., 2015). Time geography defines accessibility as an individual's capacity to reach resources or opportunities, which is influenced by their spatio-temporal movement over time. One of its key strengths lies in its ability to construct mobility patterns under constraints of speed, space, and time, using tools such as the space–time prism. These mobility patterns are often influenced by physical conditions such as natural geography or the built environment (Song, Y. and Miller, H.J., 2013; Tribby, C.P., et al., 2015).

Based on this framework, there has been much research exploring the accessibility differences faced by different groups in accessing public services. For example, several studies have examined how access to public transport is shaped by neighbourhood socio-economic status (Páez, A., et al., 2010; Wei, R. et al., 2017), while others have applied time-geographic models in spatial analysis to inform the planning and distribution of healthcare infrastructure (Kim, Y. et al., 2018). This series of studies demonstrates that time geography can be used to understand societal structural inequalities.

Within the analytical framework, Hägerstrand's (1976) three categories of structural constraints—capability constraints, coupling constraints, and authority constraints—form the theoretical core for understanding temporal inequalities.

Capability constraints refer to mobility limitations arising from an individual's physical condition (such as disability) or the availability of transport modes.

Coupling constraints highlight the requirement that individuals be in a specific place at a specific time to satisfy social functions such as work, education, or social interaction.

Authority constraints expose how institutions, organisations, and cultural norms influence people's freedom of movement through the distribution of resources and the imposition of rules.

These three constraints are embedded in various aspects of wheelchair users' everyday mobility. Underground travel constraints can be specified as time delays, route detours, irregular waiting, and the disruption of planned journeys.

It is worth noting that in recent years, some scholars have also gone beyond the methodological framework of classical time geography. For example, McQuoid, J. and Dijst, M. (2012) have proposed to bring 'emotion into time geography', emphasising that subjective experiences such as rhythm, pressure, anxiety, and uncertainty during travel are central to understanding temporal exclusion. Taking the mobility of people experiencing poverty as an example, they point out that poverty is not only a lack of income, but also a form of structural oppression in the form of temporal and spatial insecurity. This research expands time geography's understanding of mobility difficulties by framing the travel barriers disabled people face within transport systems as a form of temporal exclusion, while also considering their lived experiences of movement.

This perspective offers an important theoretical foundation for developing and analysing the Time Barrier in this study.

Based on the above theoretical framework, this paper proposes a framework for analysing the travel behaviours of wheelchair users within the underground system. As wheelchair users depend highly on accessibility infrastructure, their journeys often involve non-standard patterns, including prolonged waiting, detours, and route interruptions that differ from those of non-disabled passengers. Therefore this study proposes five travel behavioural states which form the basis for both the mapping and travel behaviour analysis.

2.4 Crip theory and Crip time

In this study, Crip theory also provides crucial theoretical support for analysing the Time Barriers encountered by wheelchair users. Crip Theory reveals the institutional bias of "normative able-bodied rhythms" embedded within urban infrastructure. Introduced by Robert McRuer in 2006, Crip Theory positions itself at the intersection of Queer Theory and Critical Disability Studies. He argues that a person does not need to be formally recognised as disabled to engage in crip practices or "become" disabled through embodied experience. The concept of crip time, which was developed to show the 'non-normative time' faced by wheelchair users. Crip Time is not merely about disabled people moving more slowly or experiencing interruptions. Instead, it critiques how dominant conceptions of time, alongside normative bodily expectations and social values, fail to accommodate the realities of diverse embodied needs (Kafer, A. 2013).

Crip time also explores the barriers hidden in everyday narratives, which may include the extra time it takes to move through space from a wheelchair, chronic illness and fatigue 'eating up' one's time (Tamar L., 2021). Samuel's (2017) describes how her life has been shaped by disability time: disability time is a time of sadness and brokenness. For disabled people, crip Time represents not only an alternative rhythm that must be adapted to, but also a lived practice of continuously reorganising life strategies. For example, when the lift out of service has to take a diversion, the new coping steps taken by the wheelchair user reflect a practical critique and reflection on ableism. As Piepzna-Samarasinha (2022) points out, the ability to 'rearrange all the elements of life', is a kind of crip time life wisdom and a fractured resistance to the logic of 'life for work'.

Thus, crip time provides a methodological framework for this research to understand that wheelchair users' behaviours of waiting, missing, repeating, requesting assistance, etc. not as personal failures, but as consequences of a system that fails to accommodate bodily diversity. Based on this understanding, the mapping section of this study incorporates a dimension specifically focused on temporal delays. Crip time also influenced my practice as a simulated traveller. In this study, I undertook two travel strategies—pushing and sitting in a wheelchair to explore the journey through embodied participation. This was not merely an observation of wheelchair users' experiences, but an effort to record how gaps in accessibility infrastructure disrupted my journey. This practice also echoes McRuer's definition of 'becoming disabled' - even without a formal diagnosis, the researcher can still experience 'crip time' as 'living with a disability, which allows for a better understanding of how disabled people's time is excluded from social structures'. Crip Time also provides a crucial ethical foundation for this study.

In summary, crip time provides a theoretical foundation for moving beyond accessibility evaluation systems centred solely on physical infrastructure. It calls for institutional recognition of diverse bodies and the temporal rhythms they inhabit. This perspective serves as one of the key methodological foundations of this study. Supported by this framework, the concept of the Time Barrier is introduced as a critical response to dominant accessibility discourses, ultimately leading to the development of the policy proposition: Time as Infrastructure.

Chapter 3: Methodology and Methods

This chapter introduces the methodological approach adopted in this study. It outlines the theoretical and methodological framework, the mapping method, sources and techniques of data collection, the reasons behind the selection of simulated travel routes and station sites, the process of designing the simulated paths, and relevant ethical considerations.

To address the first research question: Do wheelchair users experience significant time barriers during underground travel? If so, at which stages of the journey do these barriers primarily occur? — this study adopts a methodological framework grounded in phenomenology and Crip Theory. It emphasises understanding accessibility within the underground system through the lens of embodied experience and temporality. At the same time, combining the theory of Time Geography, the thesis introduces a model of five travel states specific to wheelchair users, which is used to simulate and document the occurrence of Time Barriers throughout the travel process.

This study uses a combination of mapping and simulated journey, divided into two main components:

The first part involves mapping accessibility infrastructure and wheelchair user travel routes across all Elizabeth Line stations and the Jubilee Line stations. This includes collecting data on accessibility facilities, transfer routes, and vertical circulation (e.g., number of floors and available lifts) and conducting a comparative analysis of these elements.

The second part is a simulated journey. Based on the findings from the mapping and data analysis, a selection of representative stations is made. Simulated underground journeys are conducted to simulate the travel process of wheelchair users underground, and the time spent on each travel segment is recorded to identify the most significant time barrier points in the travel process.

3.1 Methodology inspiration, and framework

3.1.1 Phenomenology

In this study, I use phenomenology as the primary methodological foundation. Phenomenology is a theoretical position on 'how experience is perceived' and a response to the existing logic of accessibility policy evaluation.

Currently, TfL's accessibility policies assess whether a station is "step-free" based on the presence of infrastructure, without accounting for the difficulties and time barriers experienced by wheelchair users in practice.

Phenomenology is important because it emphasises embodied experience. As Merleau-Ponty (1962) asserts, the body is not merely an instrument for perceiving the world; it is a site where action and meaning are generated.

When wheelchair users encounter broken lifts, unclear signage, or forced detours within the underground, their right of passage is not just truly restricted; it is the disruption of their bodily sovereignty on a perceptual level.

Phenomenology has also been used as a theory of resistance to ableism in disability-related research. As defined by Chouinard, V. (1999), ableism is a concept that takes the 'able-bodied' as its default point of departure, and centres on the 'rhythm of life of able people' in the construction and management of cities. This logic excludes the mobility rhythms of disabled people from the 'normal functioning' of public systems. This is expressed in the quest for speed, autonomous and uninterrupted movement in urban transport systems. Any travel practices deviating from these normative rhythms are often perceived as "abnormal" or a "burden".

Nario-Redmond, M.R. (2020) illustrates this experience of systematic exclusion in her poem(Figture 2).

Ableism is

When you make plans that do not include accessible venues, accessible spaces

So it becomes easier to erase me from your list.

Ableism is

Making buses accessible, but not the streets leading to the bus stop.

...and how we have to become our crip version of Rosa Parks

Every single day to this day.

Figure 2:
The poem about Ableism From Nario-Redmond, M.R. (2020). Available at: https://www.wiley.com/en-us/Ableism%3A+The+Causes+and+Consequences+of+Disability+Prejudice-p-9781119142072.

Therefore, this research adopts phenomenology as its methodological starting point, and it was used throughout the research process:

- In the mapping, the routes are not categorised according to the distribution of accessibility facility points. However, they are set up according to the user's movement status, such as waiting, detouring, and pausing.;

- In the simulated journey, I completed the whole travelling path by pushing the wheelchair and sitting in the wheelchair myself. I recorded the embodied experiences of time barriers and interruptions during the process.

3.1.2 Crip theory

In addition to phenomenology, crip theory is one of the key methodological approaches in this study. As mentioned in the literature review , crip theory provides a methodological perspective that has influenced my practice as a simulation practitioner, which I will not elaborate on here.

3.1.3 Time-Geography

After phenomenology and crip theory helped me understand time barriers from the perspectives of bodily experience and social institutions respectively, time geography provided a more specific methodological framework for this study to analyse the actual path behaviours of wheelchair users and the constraints they may be subjected to when travelling in the underground system.

The fundamental theories of time Geography have already been discussed in the literature review and will not be repeated here. In this study, I mainly refer to the three types of action constraints—capability, coupling, and capability, coupling, and authority constraints—to explain the constraints encountered by wheelchair users in the underground system, such as waiting caused by equipment failure and path detours during transfers. Based on this framework, I have summarised five common travel states for wheelchair users in the underground by combining my field observation and simulated travel experience:

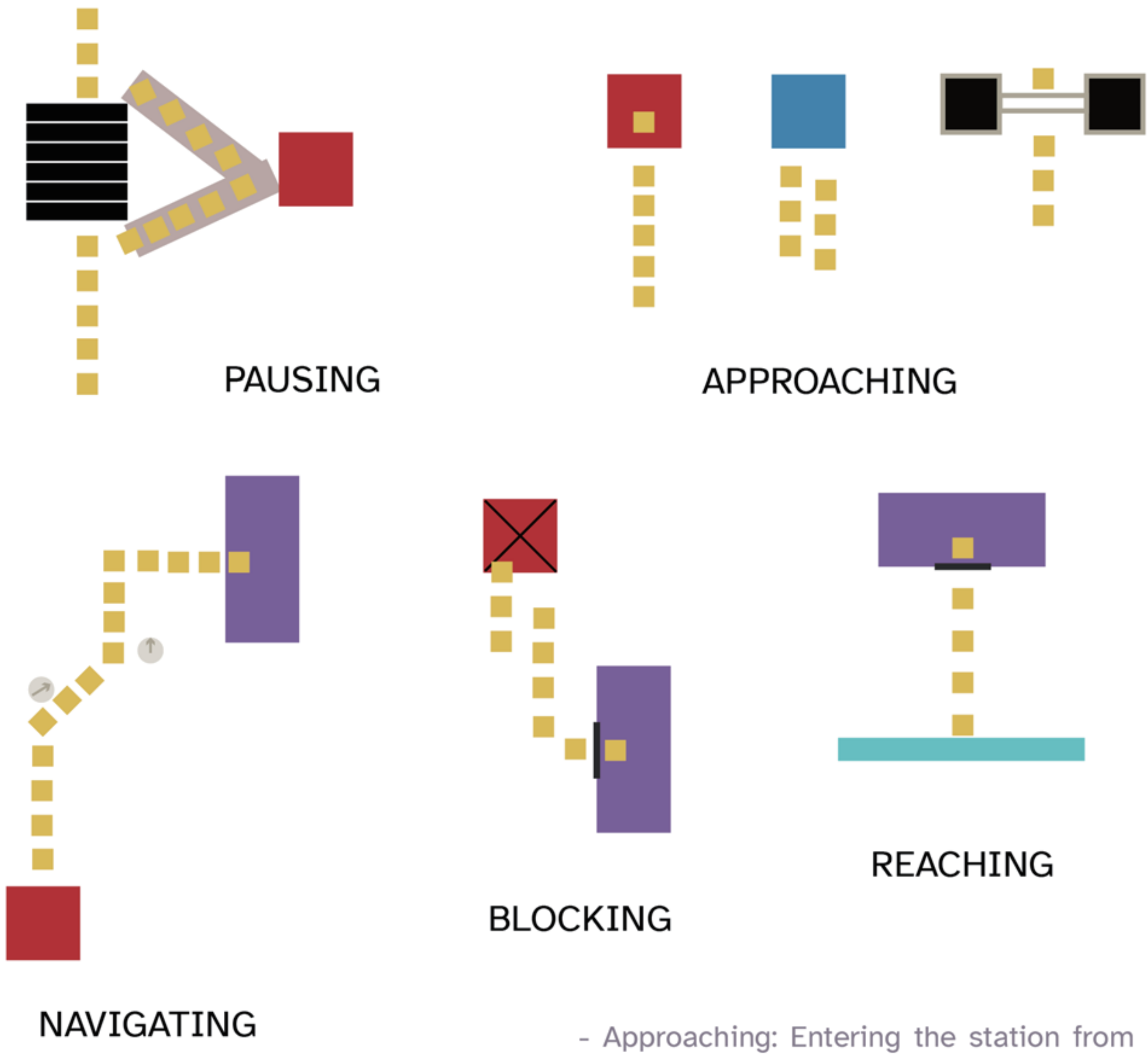
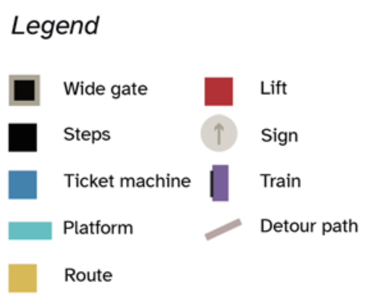


Figure 3:
Five mobility states of a wheelchair user. Source: Author, 2025.



- Approaching: Entering the station from the street, including finding accessible or step-free entrances;

- Navigating: Moving around the station, route-finding, lift usage, and interpreting signage.

- Pausing: Temporality stops caused by waiting for lifts, navigating congestion, or encountering temporarily unavailable facilities.

- Blocking: Complete interruptions caused by blocked routes, lack of assistance, or overcrowding.

- Reaching: Completing entry or exit, and arriving at the destination.

These five travel states were used throughout the research process. For example, during the mapping phase, they helped me label the travelling paths of wheelchair users at different stations. Through this state-based path analysis, the study seeks to move beyond the traditional assessment of 'presence or absence of facilities' and incorporate time and experience into assessing accessibility.

Overall, phenomenology, crip theory and time-geography collectively form the methodological framework of this research.

3.2 Research Methods Overview

In this research, the reason for choosing mapping and simulated travels as the primary research methods is the research problem's need, from the research question's specific demands. The central focus of this study—the Time Barrier—is closely linked to wheelchair users' embodied experiences of delay, pausing, and waiting within the underground system. These forms of temporal disruption are challenging to identify and analyse through conventional qualitative methods such as interviews or surveys, as such approaches often fail to reveal the spatial patterns and structural distribution of time-based barriers. Therefore, this study chose mapping and simulated travels, which are better suited to addressing the core concerns of the study.

3.3 Site-Based Method Design

This section outlines how the Elizabeth Line and the Jubilee Line were selected as case studies for this research. It details the specific mapping method employed, followed by field data collection through on-site investigation. The data were analysed using radar charts, and based on the outcomes of this analysis, representative stations and routes were selected for the simulated journeys.

3.3.1 Selection of tube lines

London has 11 underground lines, including the recently constructed Elizabeth Line and other legacy routes. Due to the scope of the study and resource constraints, it was impossible to make comprehensive measurements and comparisons of all lines.

Therefore, after conducting a preliminary analysis of the 11 lines based on four key dimensions, I selected the Elizabeth Line and the Jubilee Line as case studies. This choice ensures that the research remains focused and feasible, while offering representative insight into the presence of Time Barriers in the London Underground system.

The first dimension: Accessibility coverage rate:

In the London Underground system, the availability of step-free access is a key factor that directly influences whether or not a wheelchair user chooses to use a particular station. Therefore, the proportion of accessible stations on a line is a key indicator for assessing its suitability for simulated journey-based research.

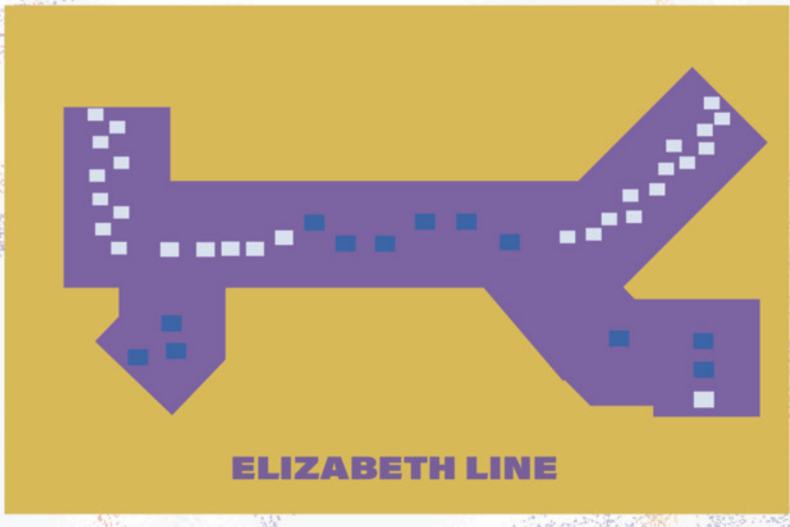
According to official station data published by TfL (Transport for London, 2024), only two lines have more than 50 per cent accessible platform coverage by 2024:

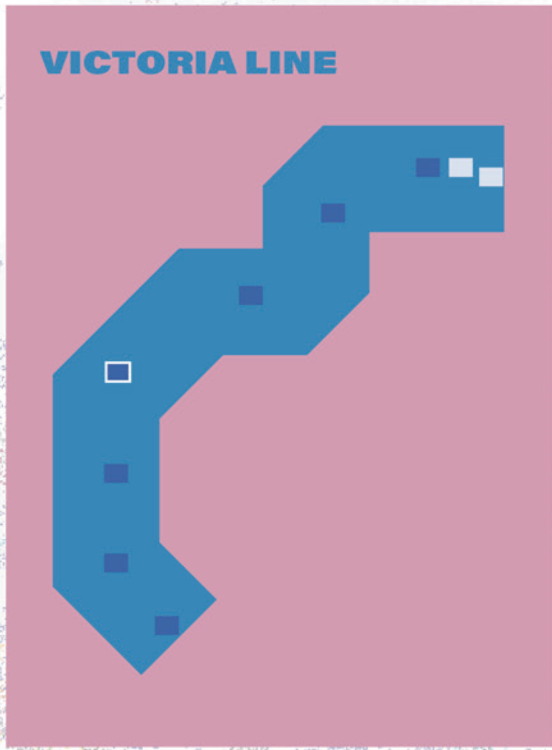
The Elizabeth Line is the only line with 100% step-free access across all 41 stations. Due to its 1999 extension and refurbishment, the Jubilee Line now offers step-free access at 17 of its 27 stations—approximately 62.9% coverage.

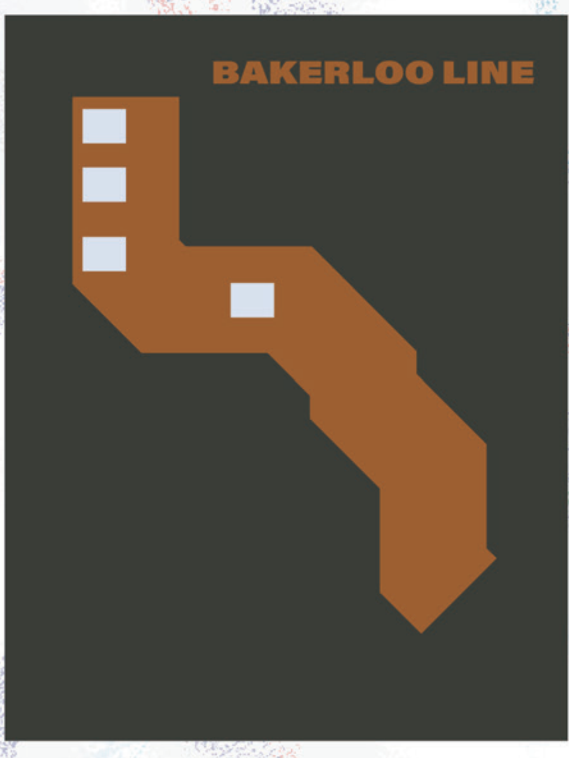
In contrast, other major lines show significantly lower levels of accessibility (see Figure 4.), for example: Piccadilly Line: 20 out of 53 stations (approx. 37.7%) Northern Line: 13 out of 50 stations (approx. 26%) Central Line: 13 out of 49 stations (approx. 26.5%) Bakerloo Line: 4 out of 25 stations (only approx. 16%)

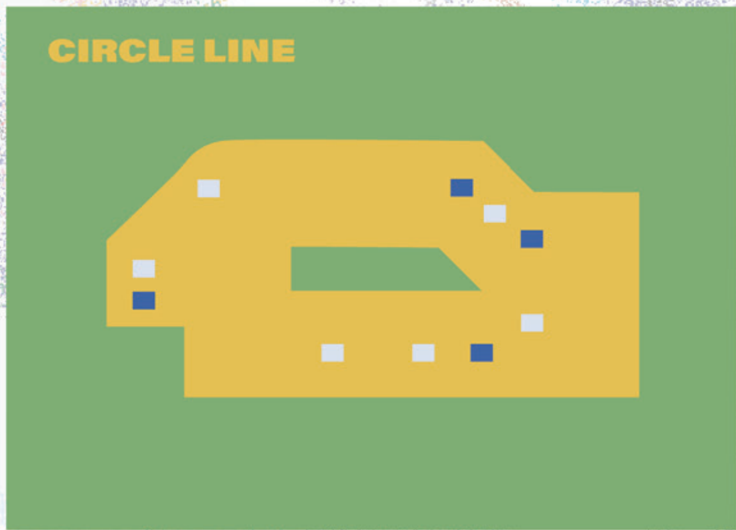
Based on this comparison, the Elizabeth Line and Jubilee Line, which have newer structures and more complete accessibility coverage, are chosen as case studies not only for their practical accessibility but also for identifying the time barriers that wheelchair users may face despite the presence of facilities.

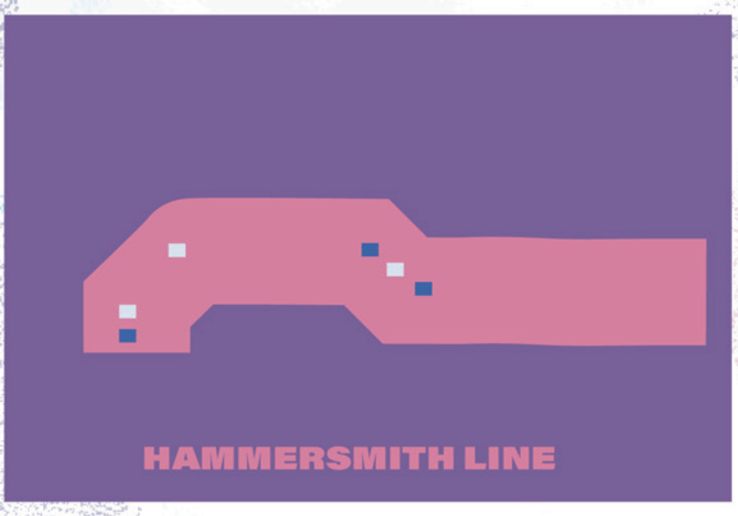
In summary, crip time provides a theoretical foundation for moving beyond accessibility evaluation systems centred solely on physical infrastructure. It calls for institutional recognition of diverse bodies and the temporal rhythms they inhabit. This perspective serves as one of the key methodological foundations of this study. Supported by this framework, the concept of the Time Barrier is introduced as a critical response to dominant accessibility discourses, ultimately leading to the development of the policy proposition: Time as Infrastructure.

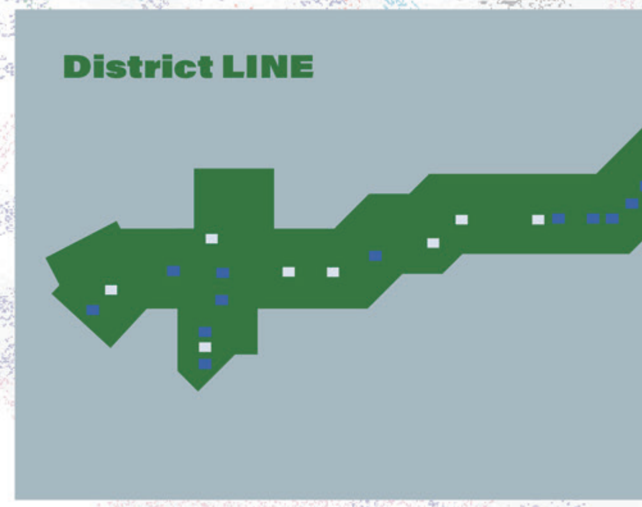




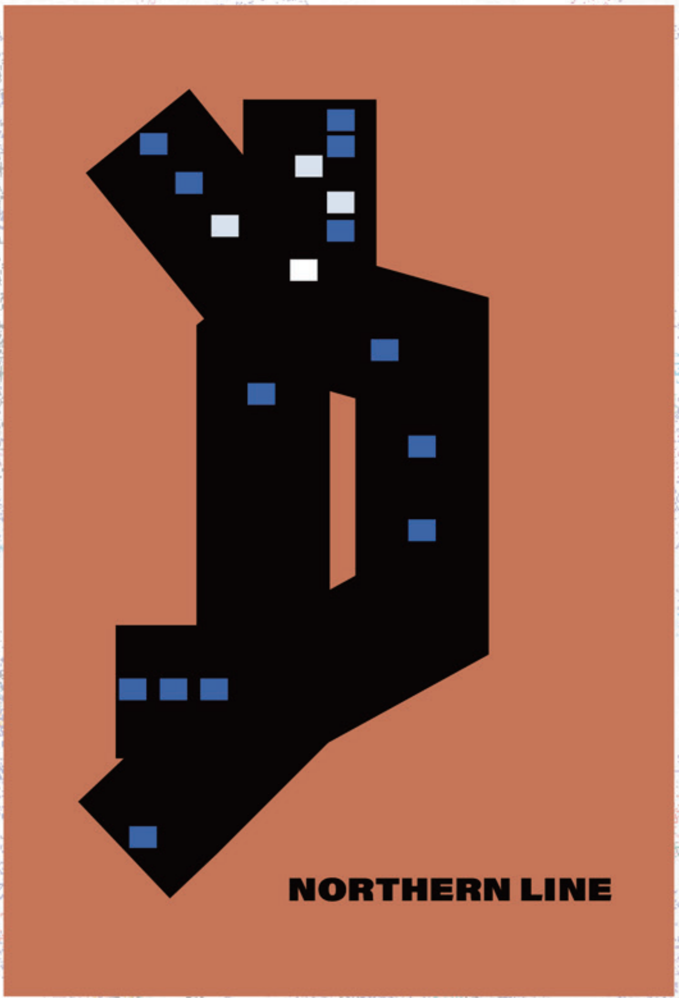


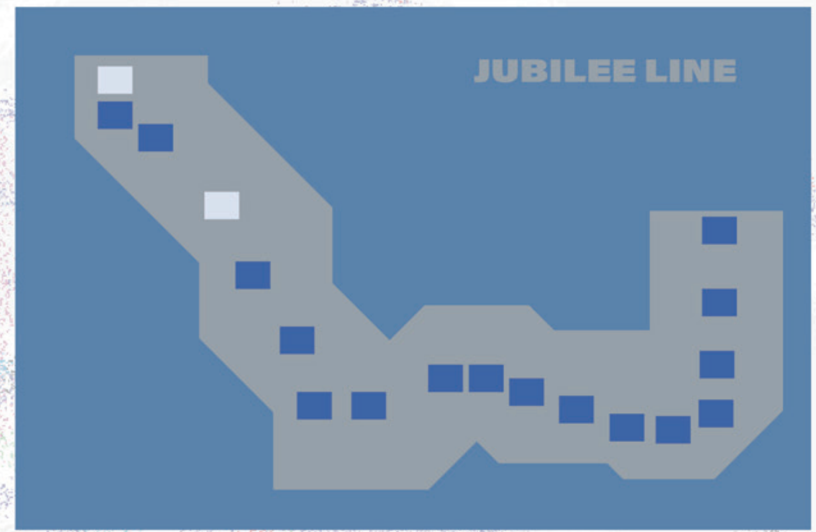


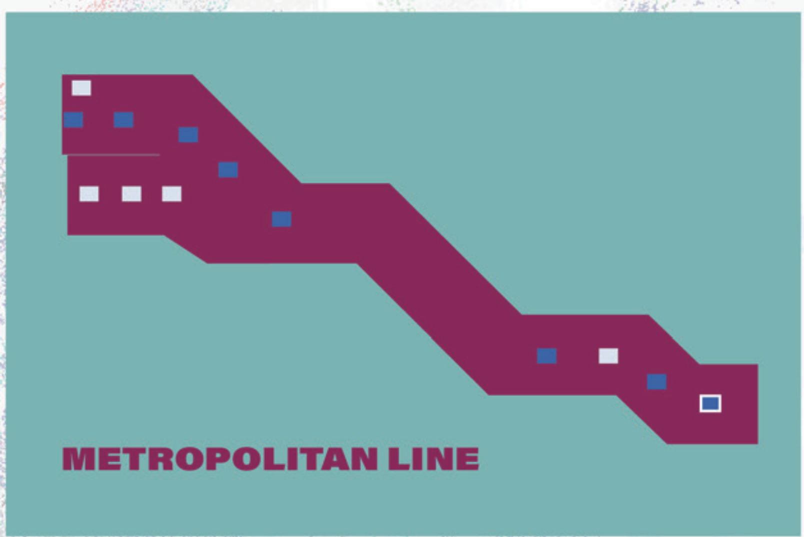


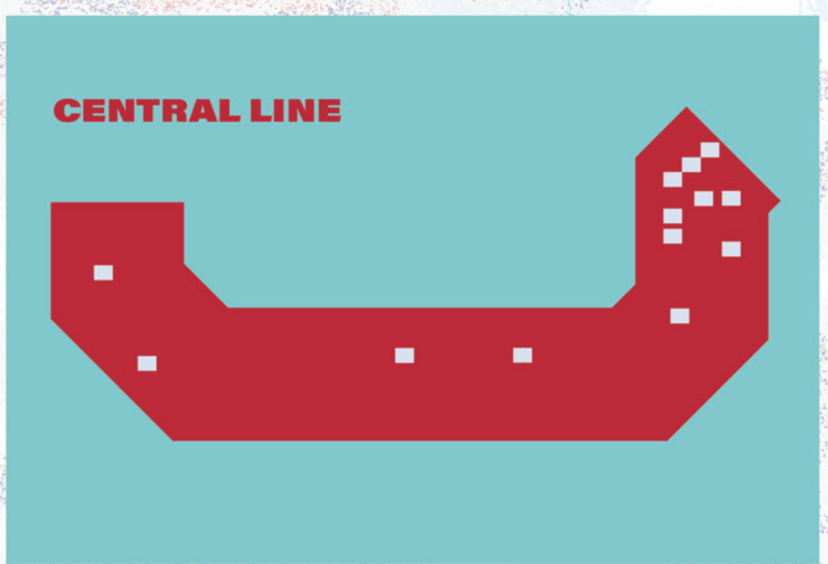


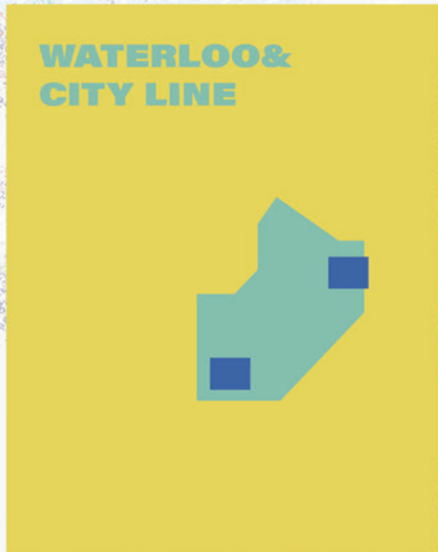
Step-free from Street to Train Station











Step-free from Street to Platform Station

LINE NAME	STEP-FREE /TOTAL STATION	%	Zone 1 station number /Z	YEAR	Rank/Annual people
Elizabeth line	41/41	100%	5/1-9	2022	2/223839367
Water-loo&City line	2/2	100%	2/ 1	2022	11/93425771
Jubilee line	17/27	62.9%	6/1-5	1979	3/223839367
Victoria line	7/16	43.75%	4/1-3	1968	4/194533863
District line	16/60	41.60%	5/1-6	1868	7/129658975
Metropoli-tan line	13/34	38.20%	3/1-9	1863	6/143046252
Hamer-smith line	11/29	37.90%	4/1-4	1863	5/174185999
Piccadilly line	20/53	37.70%	3/1-6	1906	9/125925087
Circle line	10/28	27.70%	8/1-2	1884	1/287136440
Central line	13/49	26.50%	2/1-6	1900	10/102226515
Northern line	13/50	26.00%	4/1-5	1890	8/128043686
Bakerloo line	4/16	16.00%	1/1-12	1906	12/31139747

All data for the above lines are sourced from TfL (2025).

Why choose Elizabeth line and Jubilee line as case study

London has 11 underground lines, including the recently constructed Elizabeth Line and other legacy routes. Due to the scope of the study and resource constraints, it was impossible to make comprehensive measurements and comparisons of all lines.

Therefore, after conducting a preliminary analysis of the 11 lines based on four key dimensions, I selected the Elizabeth Line and the Jubilee Line as case studies. This choice ensures that the research remains focused and feasible, while offering representative insight into the presence of Time Barriers in the London Underground system.

The first dimension: Accessibility coverage rate

The second dimension: Period of construction and renewal of lines

The third dimension : The coverage of tube lines in London's different transport zones

The fourth dimension: Zone 1 step-free station footfall

The second dimension: Period of construction and renewal of lines

The period of construction and renewal of lines reflects the logic of the configuration of their accessibility in the institutional context.

The Elizabeth Line opened in 2022 and is the latest line built on the London Underground system. From its outset, the line was designed to incorporate the accessibility standards in the Equality Act 2010 fully. The station structure systematically considers the pace and needs of wheelchair users: all entrances and exits, lifts, ticket gates, and signage are planned and configured according to the unified accessibility standards, reflecting the high priority given to accessibility at the institutional level on the new line.

In contrast, although the Jubilee Line was first built in 1979, it has carried out large-scale facility upgrades at its core stations such as Westminster, Canary Wharf and London Bridge during the reconstruction of its southern extension in 1999 and the many rounds of renewal after 2010. Although the path structure is not as straightforward as that of the new line, it is representative of the old line with a high coverage rate of renovation. Most of the earlier lines, such as the Bakerloo line (1906), Central line (1900), and Northern Line (1890), have seen only limited, station-specific lift retrofits. Their infrastructure is mainly outdated and has not undergone systematic accessibility upgrades. Therefore, the newer Elizabeth and Jubilee lines were chosen to represent the current accessibility standard on the London Underground.

The third dimension is the coverage of tube lines in London's different transport zones.

Another important consideration when selecting simulated travel routes is the geographic coverage of the underground lines across London's transport zones. The coverage of the London Underground lines is divided into Zones. In order to be representative, the lines chosen should cover as much of London as possible and pass through London Zone 1[1] (central London).

In TfL's existing main Tube lines, only the Elizabeth Line provides full coverage from Zone 1 to Zone 9, spanning east and west London. It provides the highest degree of spatial connectivity, with five stations located in Zone 1, all of which meet the step-free from street to train standard. The Jubilee Line covers Zones 1-5, extending from southeast to northwest London. Zone 1 includes seven stations, six step-free from the street to the train. The number and quality of accessible stations within Zone 1 for both lines are key reasons for their selection in this study.

Although most other lines are concentrated in Zones 1-5, they exhibit significant limitations in accessibility coverage and infrastructure quality. For example, although the Central and Northern lines have multiple stations in Zone 1, Central has only two step-free stations from street to platform, and Northern has four. The rest of the line zoning is shown in Figure 5.

Footnote 1: Zone 1 is the most central business, transport and tourist area in London, with more complex stations, interchanges and population movement, making it the most critical area for accessibility testing and identifying time barriers.

The fourth dimension: Zone 1 step-free station footfall

This study also considers annual passenger volume at step-free stations located within Zone 1 to measure the carrying capacity of the infrastructure in use. Since TFL does not publish specific data on wheelchair user travel, this study uses the total annual entries. It exists at these stations as a proxy indicator for evaluating the frequency and intensity of use of step-free routes.

According to the data (Figure 5),[2,3] the Circle Line has eight step-free stations in Zone 1 and ranks first in total passenger volume. The Jubilee Line and Elizabeth Line follow in second and third place, respectively, indicating their high utilisation within central London.

Considering the four dimensions, the Elizabeth line and the Jubilee line represent all four dimensions and serve as the case study lines for this research.

Footnote 2: The Waterloo& City line, located entirely in zone 1 and step-free throughout, is not representative because there are only two stations.

Footnote 3: The data covers 30 March 2024 to 30 March 2025, as illustrated in Figure 5.

3.3.2 Mapping the Infrastructure

Mapping is one of the key methods in this study. It shows the spatial distribution of accessible infrastructure and helps me understand the actual role of these facilities in the travelling process from the perspective of wheelchair users. Rather than recording 'whether the facilities exist,' the mapping process focuses on how wheelchair users use these facilities to complete a travel route.

The mapping process was conducted in two stages. The first stage involved an on-site investigation and data recording. Fieldwork was carried out on 20 March, 15 April, and 1 May 2025, focusing on major stations along the Elizabeth Line and Jubilee Line. Initial annotations were made using Station Master platform data and QGIS basemaps.

During this stage, I used sketches to record wheelchair travel paths on accessible platforms and collected the following information:

The time and distance to walk from the carriage to the exit,

The number of lifts and the number of lift transfers,

The floor structure of the station,

The number of decision points (locations where a directional choice is required),

The time takes from the train to seeing the first accessibility signage;

The number and location of wide gates,

The distribution of Help Points and Assistance Points.

Figure 6 shows selected sketch samples produced during the mapping stage.

The second stage was mapping the data using QGIS and Adobe Illustrator.

Based on the five travel states model for wheelchair users, each segment of the travel route was categorised on the mapping. For overground stations, I mainly used QGIS for mapping;

Figure 7 shows an example of mapping for Elizabeth overground station. Additional station maps will be included in the design portfolio.

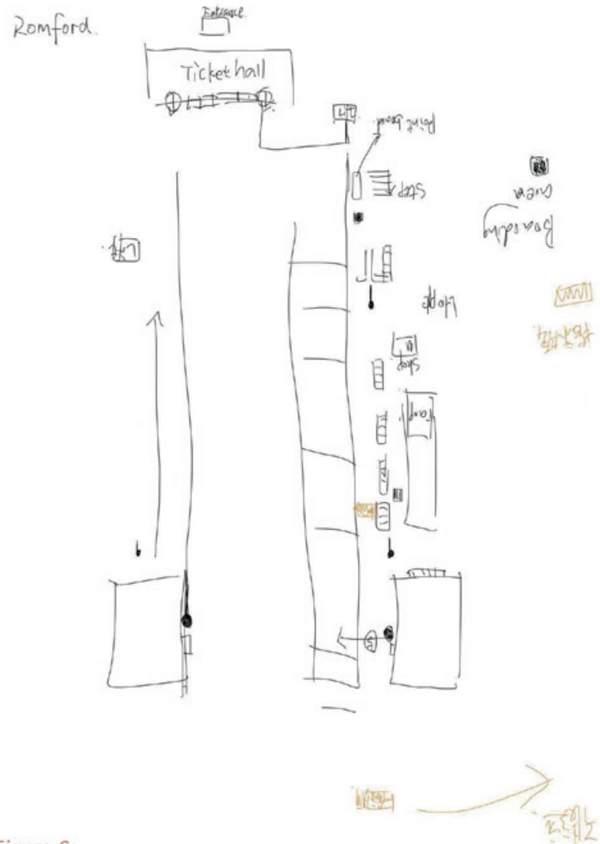
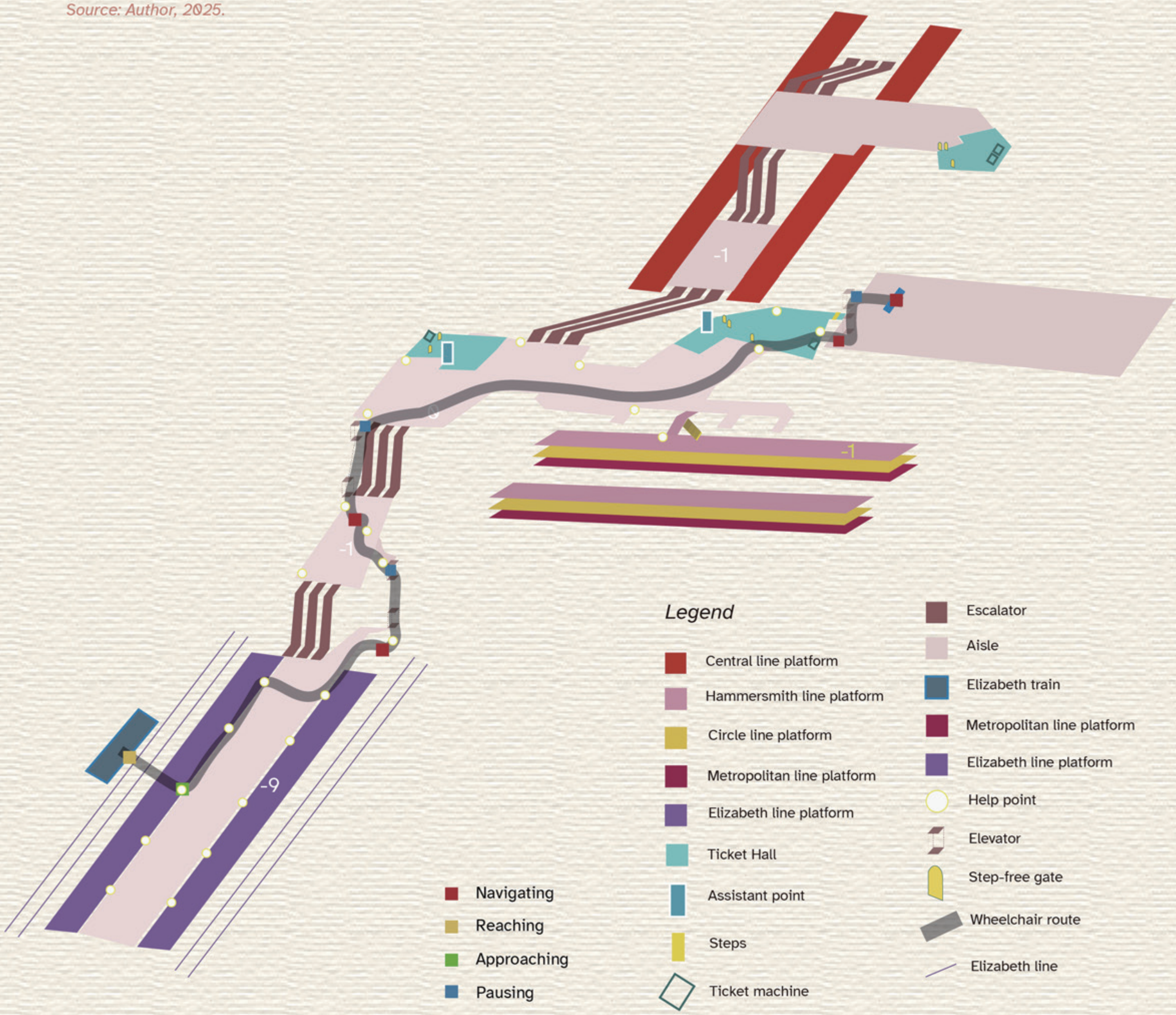


Figure 6:
Sketch samples for mapping the station in Romford Station.
Source: Author, 2025.

I completed the mapping for underground stations using structural diagrams from the Station Master App and field observations.

Figure 8 shows the mapping example for Liverpool Street Station on the Elizabeth Line. The portfolio will also include other station mapping.

Figure 8: [4]
Liverpool Street Station Mapping.
Source: Author, 2025.

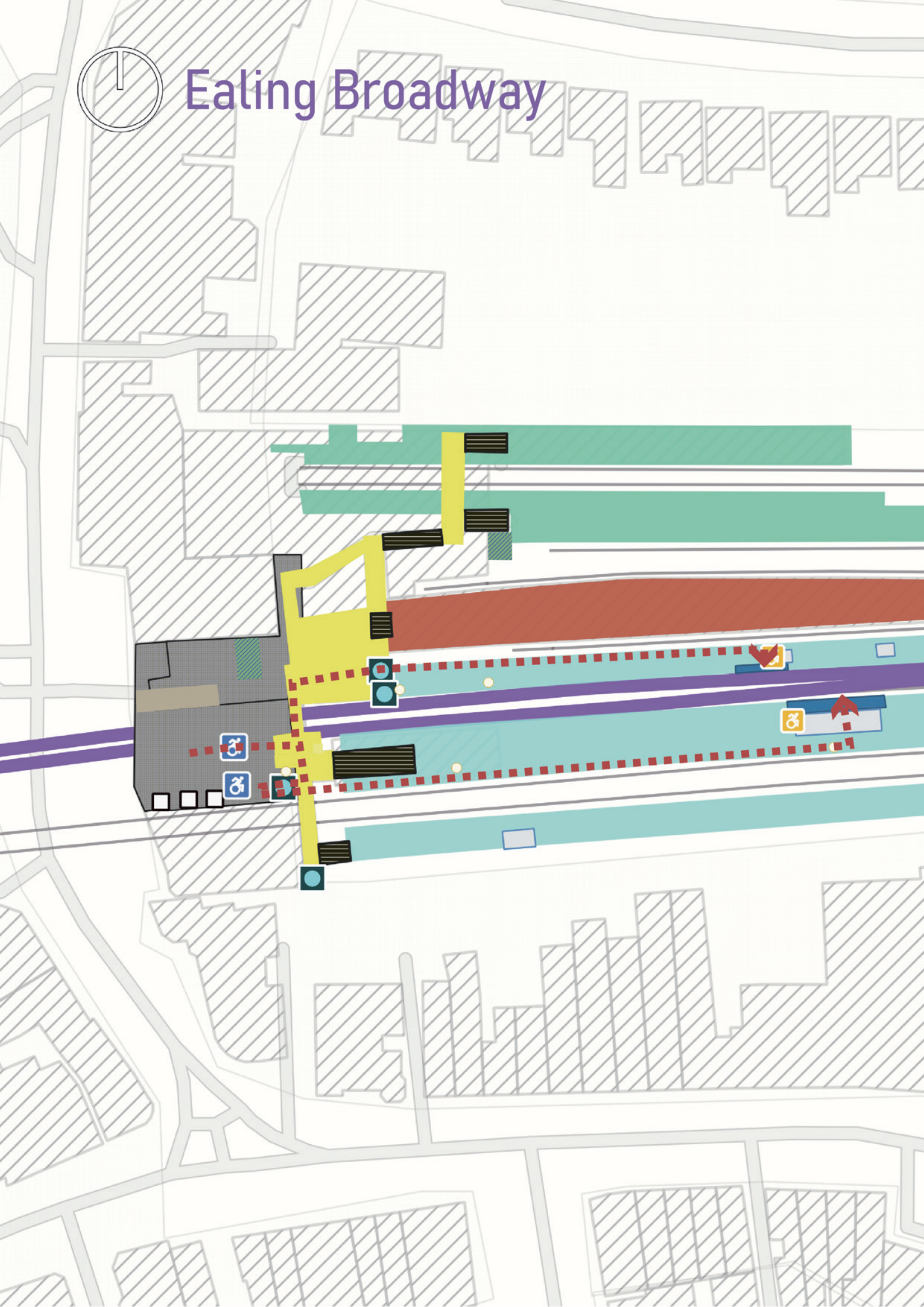


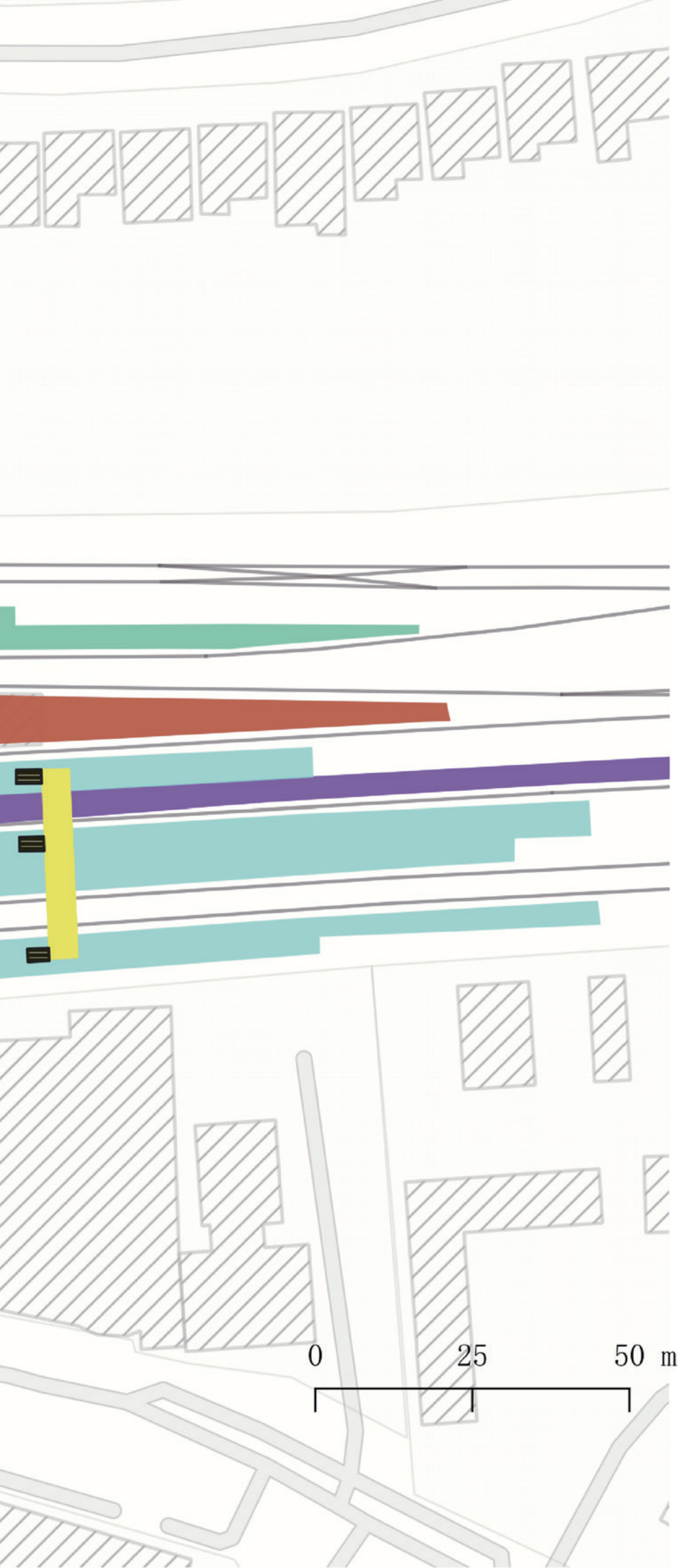
The mapping results clearly show wheelchair-accessible travel paths and the distribution of accessibility infrastructure within each station. These outputs are used to guide the selection of stations for subsequent simulated journeys.

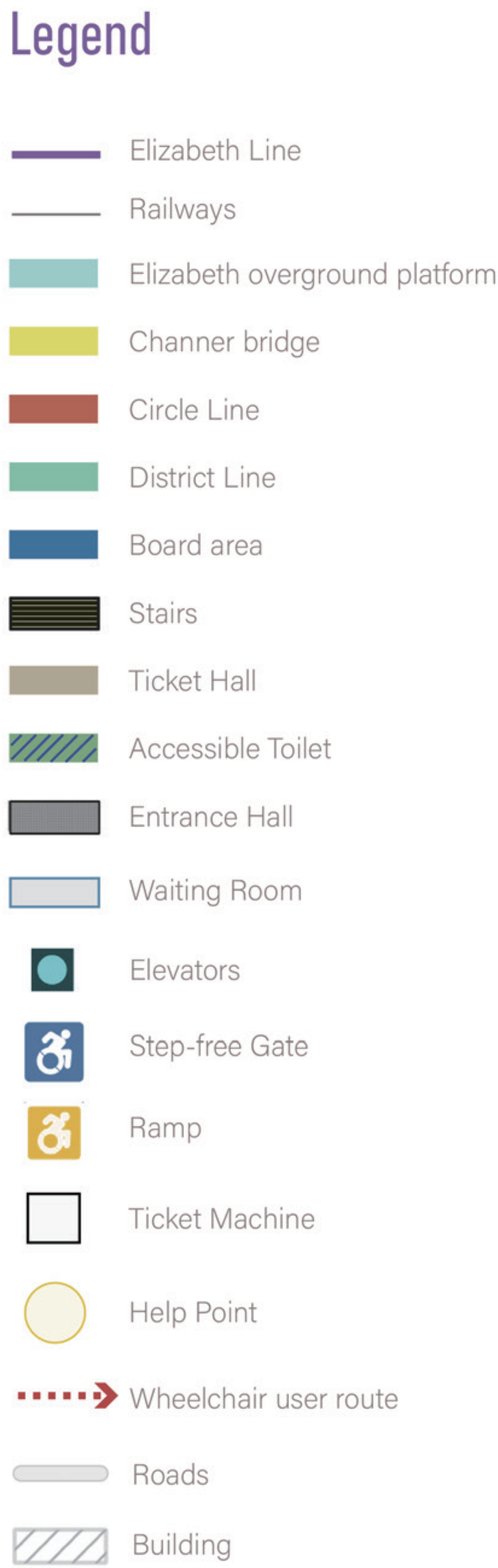
Since the TFL travelling map does not provide complete information on step-free routes,

wheelchair users must often locate accessible paths independently. Therefore, the mapping results can guide the step-free route to help wheelchair users.

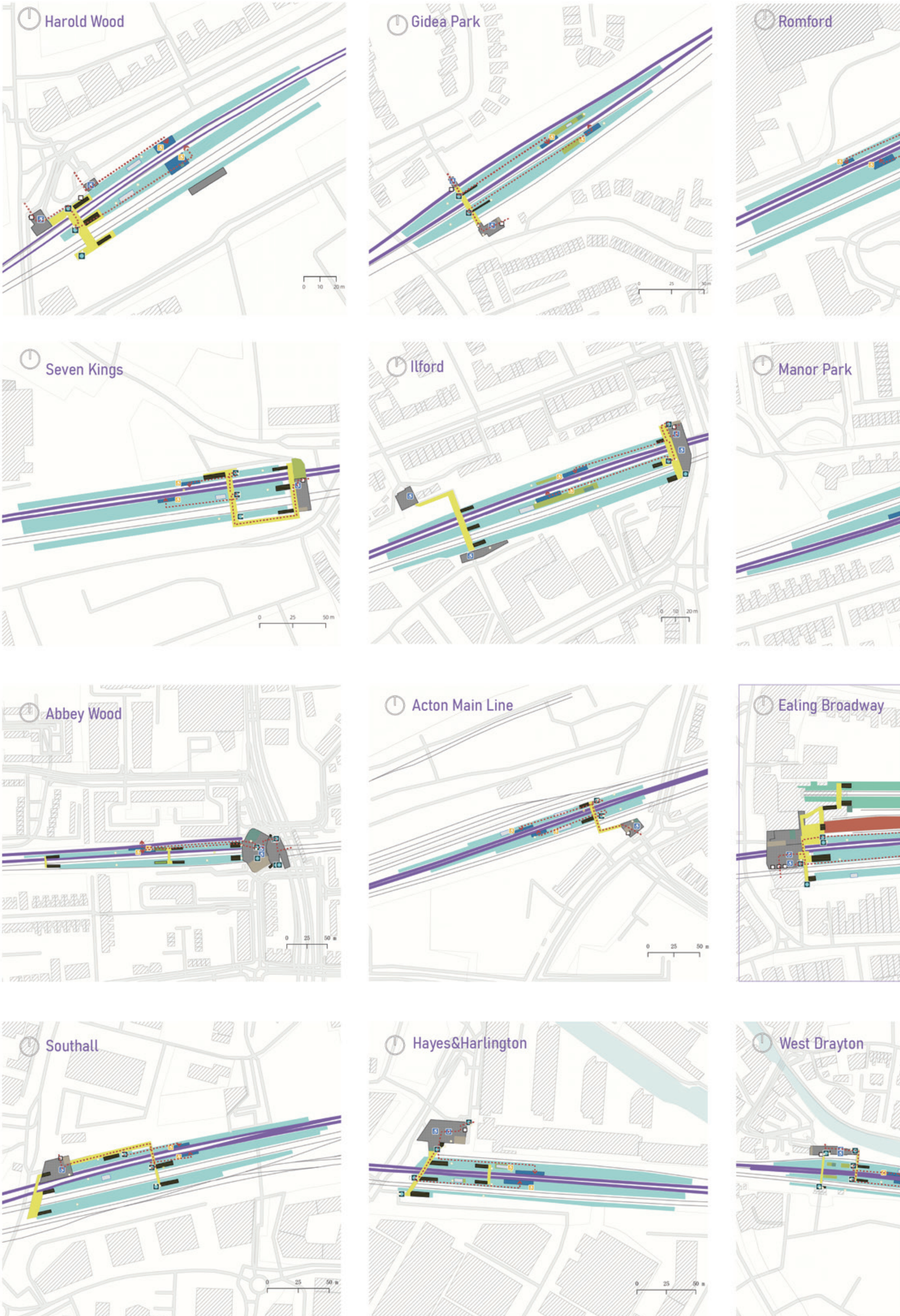
Ealing Broadway



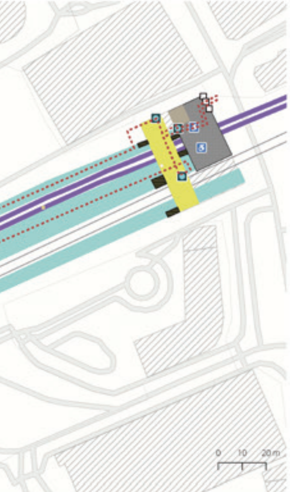


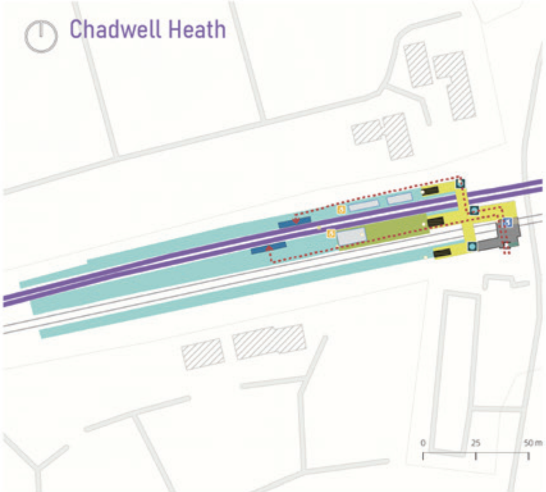


An example mapping of Elizabeth overground station



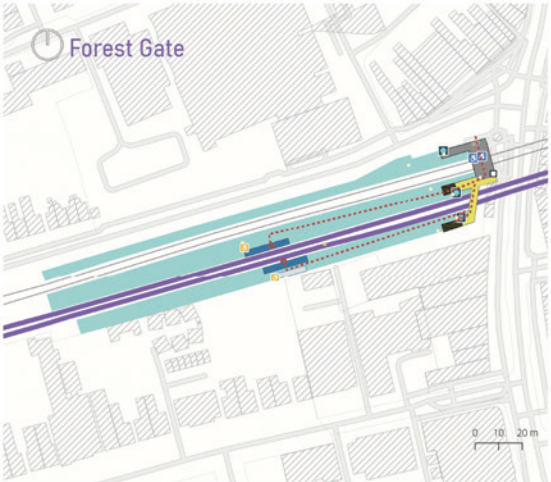
Harold Wood
0 10 20 m
Gidea Park
0 25 50 m
Romford
Seven Kings
0 25 50 m
Ilford
0 10 20 m
Manor Park
Abbey Wood
0 25 50 m
Acton Main Line
0 25 50 m
Ealing Broadway
Southall
0 25 50 m
Hayes&Harlington
0 25 50 m
West Drayton

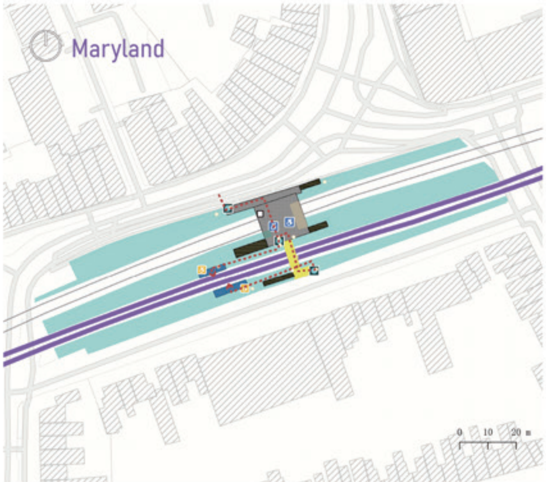

0 10 20 m

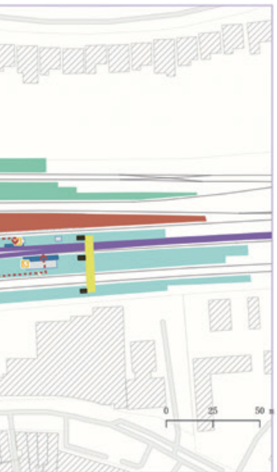

Chadwell Heath
0 25 50 m

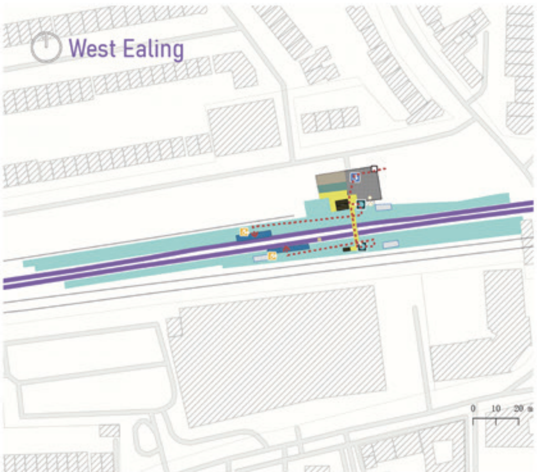

Goodmayes
0 10 20 m


0 25 50 m

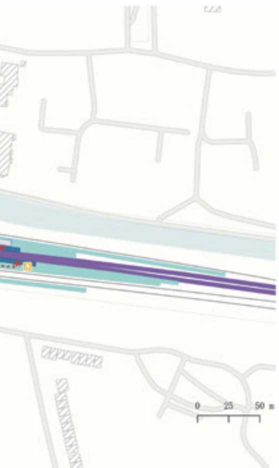

Forest Gate
0 10 20 m

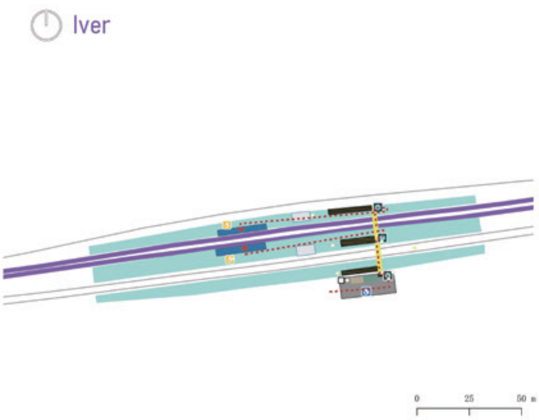

Maryland
0 10 20 m

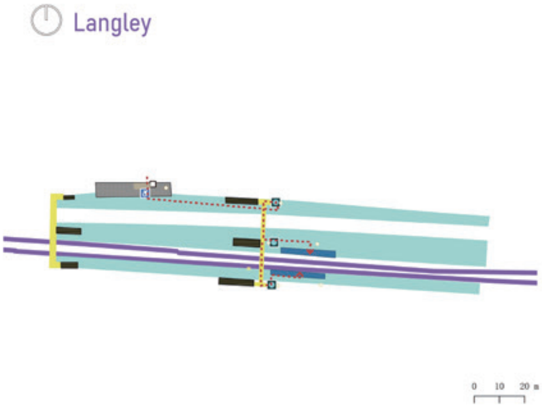

0 25 50 m


West Ealing
0 10 20 m

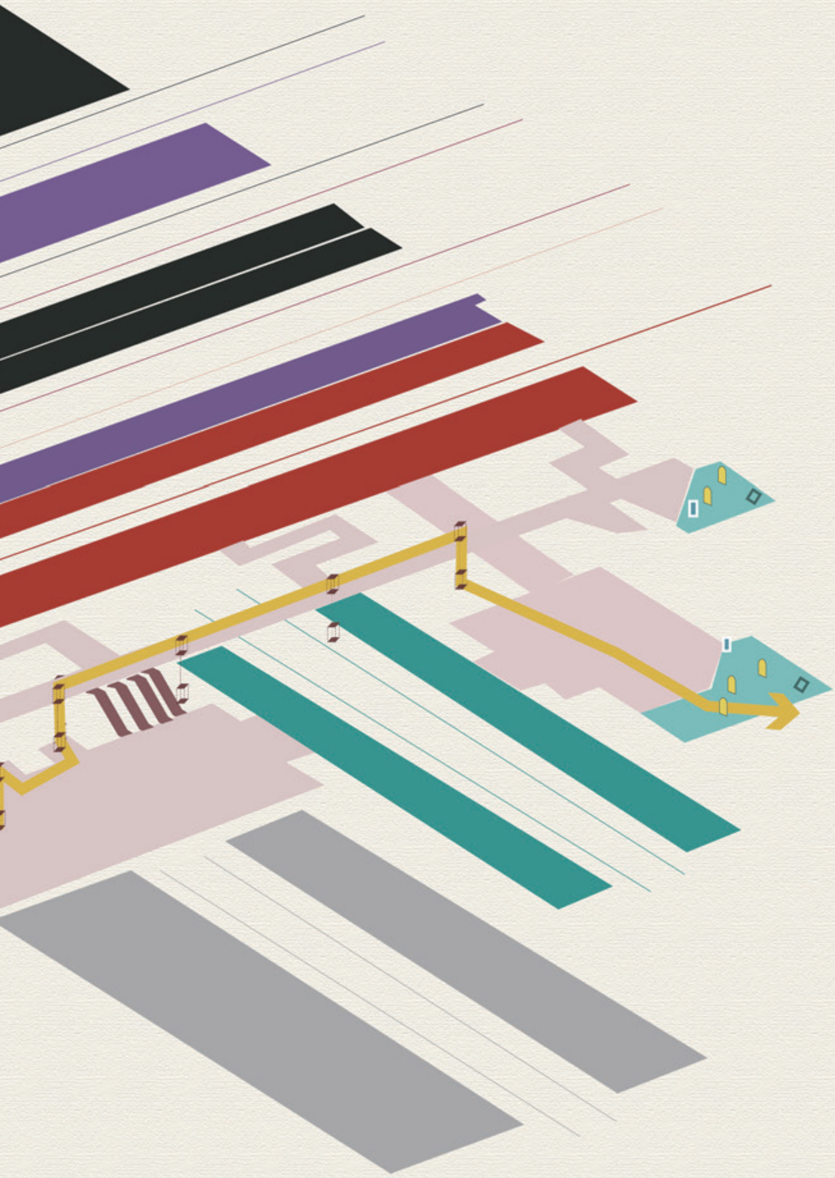

Hanwell
0 10 20 m


0 25 50 m


Iver
0 25 50 m


Langley
0 10 20 m

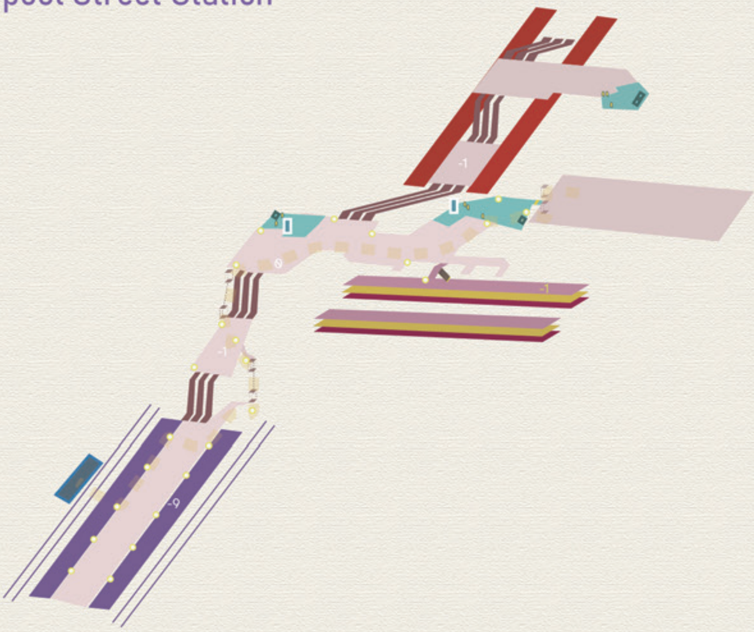
Stratford Station



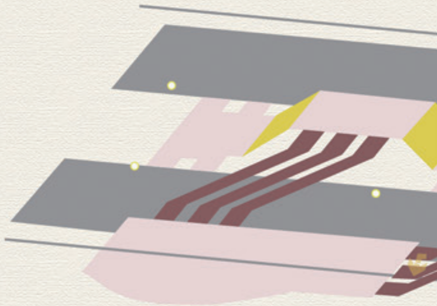
Legend

- Overground platform
- Railway platform
- DLR Line platform
- Central line platform
- Elizabeth line platform
- Jubilee line platform
- Ticket Hall
- Assistant point
- Steps
- Ticket machine
- Escalator
- Aisle
- Help point
- Elevator
- Step-free gate
- Wheelchair route
- Underground line

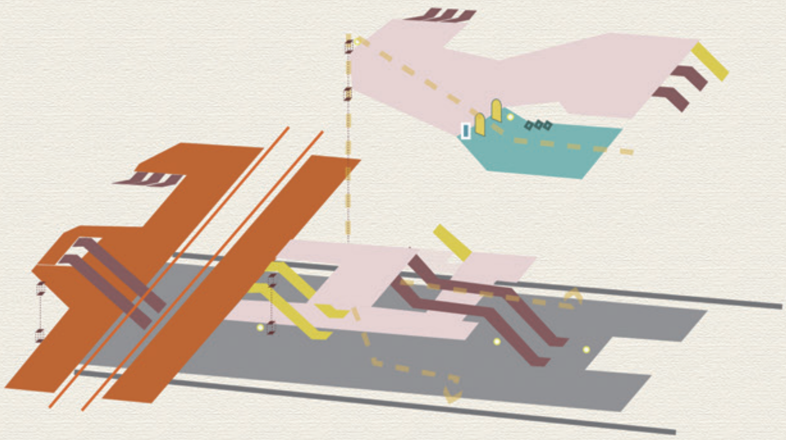
Liverpool Street Station



Southwark Station

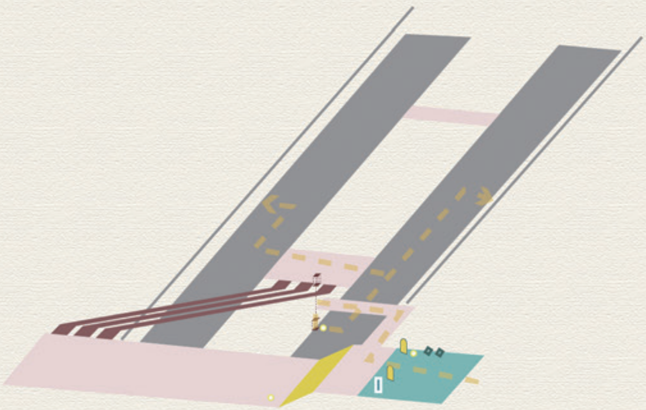


Canada water Station

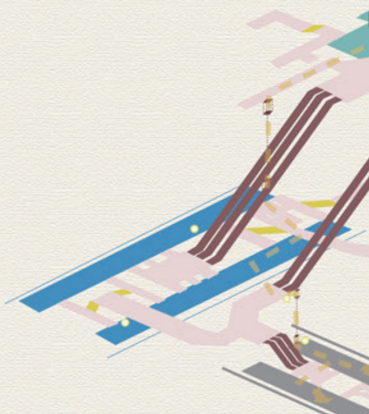


Westminster Station

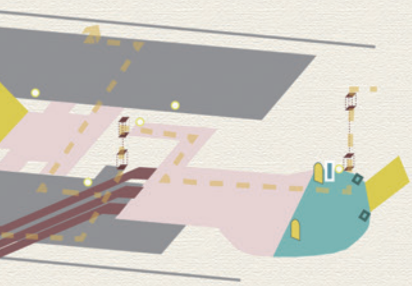
Bermondsey Station



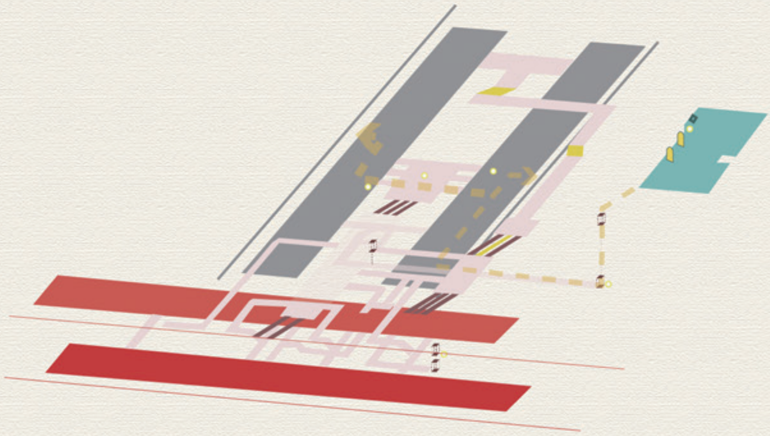
Green park Station



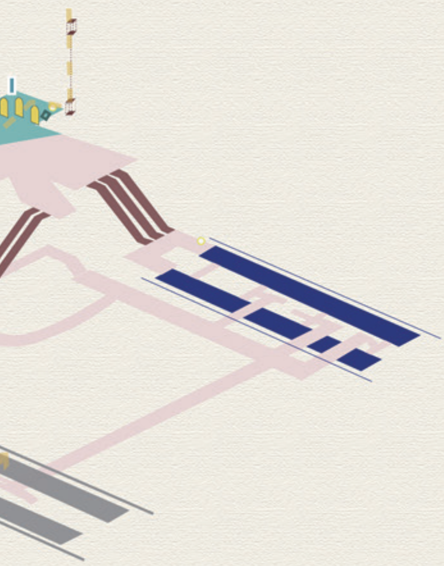
Waterloo Station

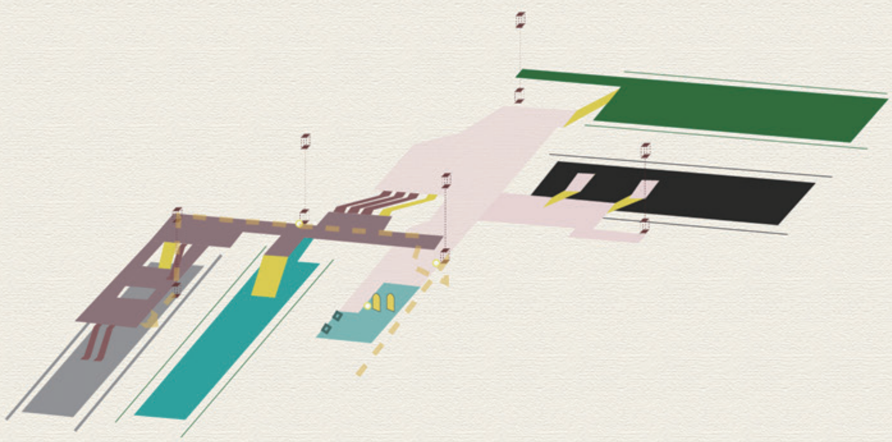


Bond street Station

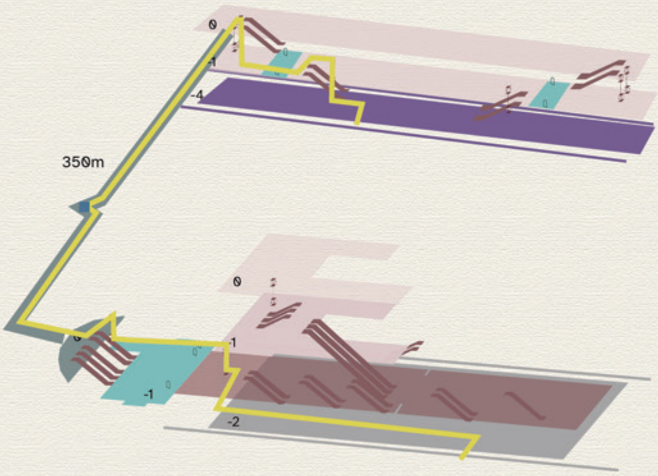


West Ham Station

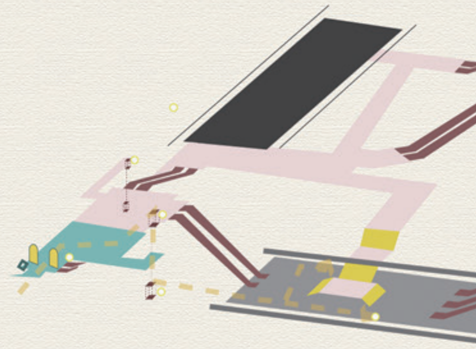




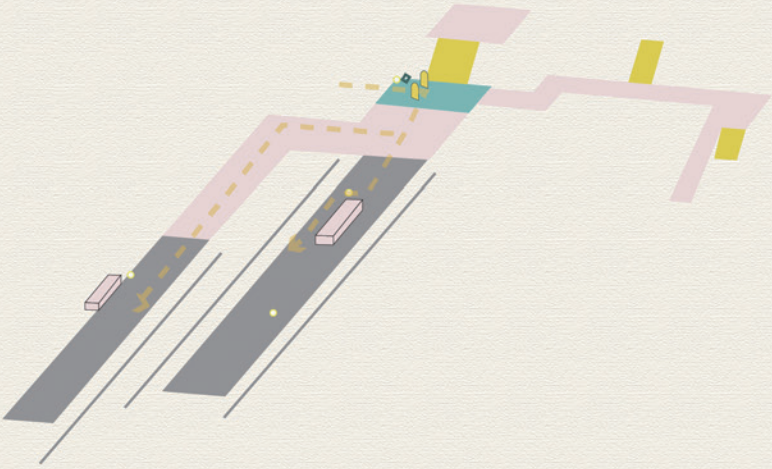
Canary Wharf Station



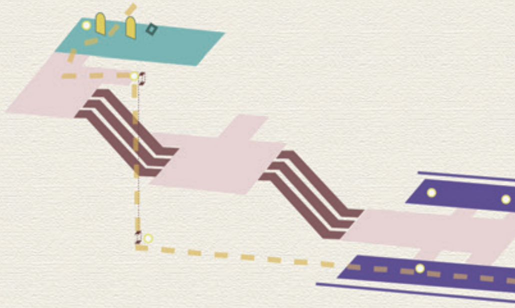
London bridge Station



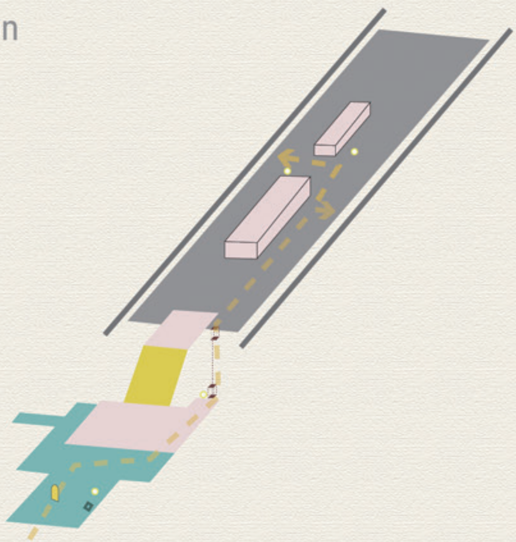
Stanmore Station



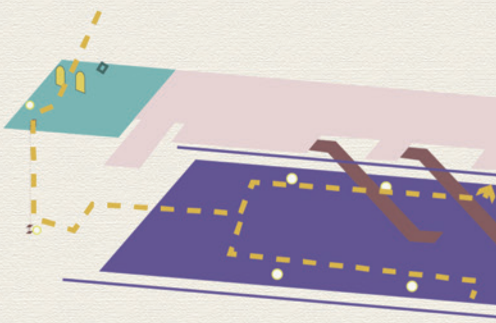
Bond Street Station



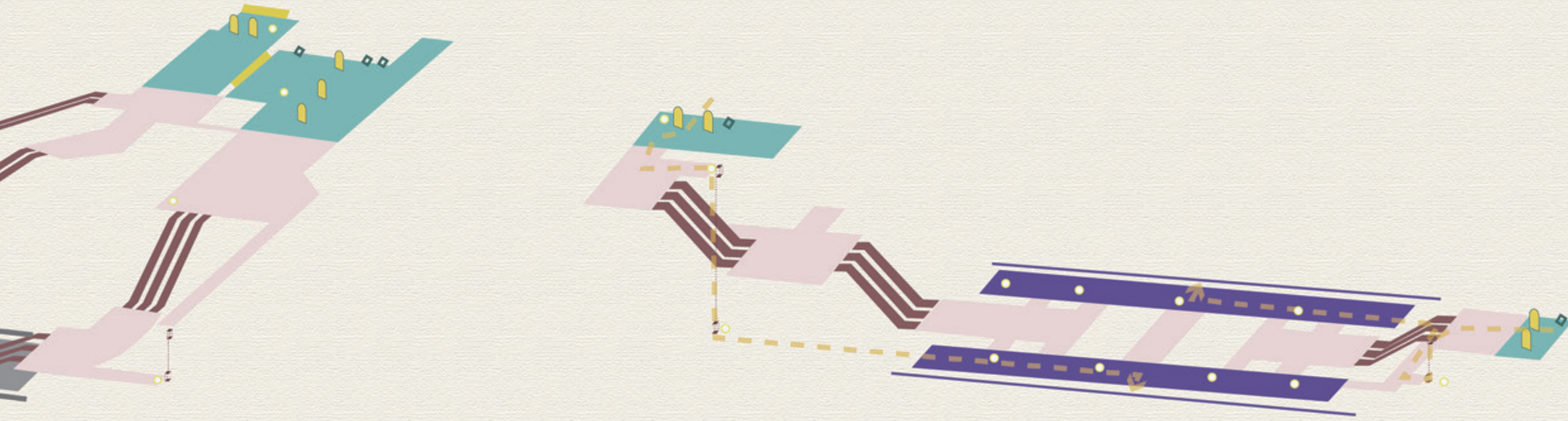
Kilburn Station



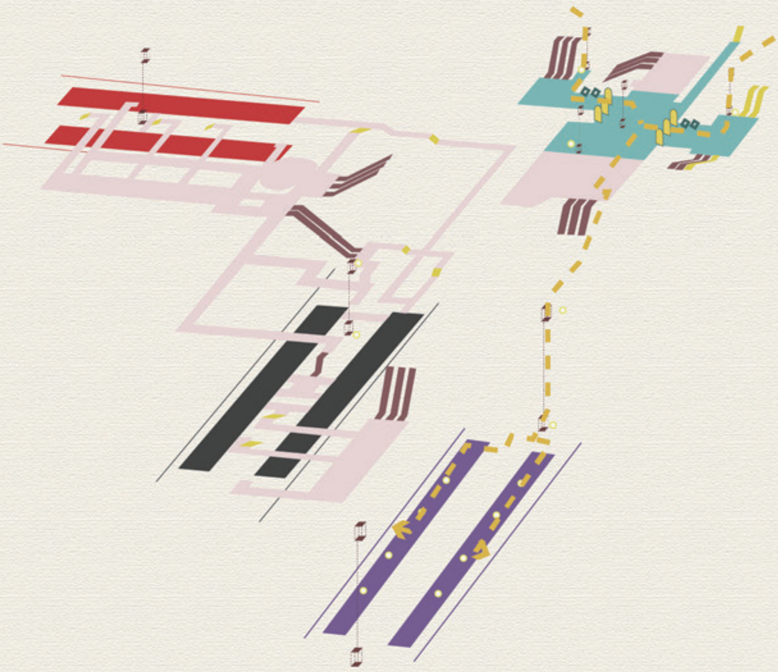
Custom House Station

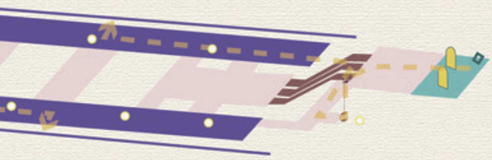


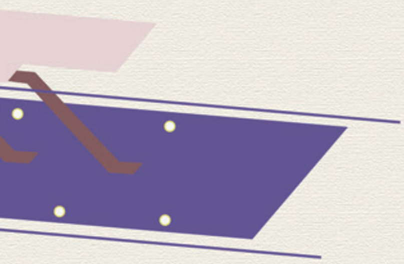
Farringdon Station



Tottenham Court Road







□3.3.3 Radar-Based Accessibility Evaluation□[5]

The data collected through mapping was further systematised and translated into radar charts to evaluate and score each station. These scores served as a key reference for selecting stations for the simulated travel stage of the study.

This research developed a radar chart evaluation framework consisting of eight dimensions, designed to quantify various aspects of the structural barriers wheelchair users may encounter during their journeys through stations.

Dimension 1: Number of Elevators (Path-based)

Lifts are the most critical element of accessibility infrastructure for wheelchair users and key points for potential time barriers. Each additional lift increases the likelihood of pausing states. This dimension counts the minimum number of lifts required to complete an accessible route.

Dimension 2: Vertical Levels (Floor Count)

The number of vertical levels reflects a station's spatial depth and structural complexity. Greater vertical complexity increases the likelihood of pausing or blocking events along the route.

Dimension 3: Number of Decision Points

This dimension records the number of key decision points along the step-free route, where users must choose a direction. More decision points increase the risk of delays, uncertainty, or disorientation, leading to pausing and blocking.

Footnote 5: Due to the excessive amount of statistical data, the eight-dimensional statistical data of each site will be displayed in the portfolio.

Dimension4： Wayfinding Signage Efficiency

The clarity and efficiency of signage affect route smoothness during the approaching and navigating phases. Poor signage leads to delays and increases the occurrence of pausing states.

Dimension 5: Number of Pausing Risk Points

This dimension counts potential pausing risk points, such as locations requiring lift access, staff assistance, or areas prone to congestion, that may contribute to time delays.

Dimension6： Train-to-Exit Travel Time

The time required to travel from the train to the station exit reflects route complexity and serves as a core metric for identifying time barriers. It is based on simulated journey data.

Dimension 7: Accessible infrastructure Crowd Weight Index (CWI)

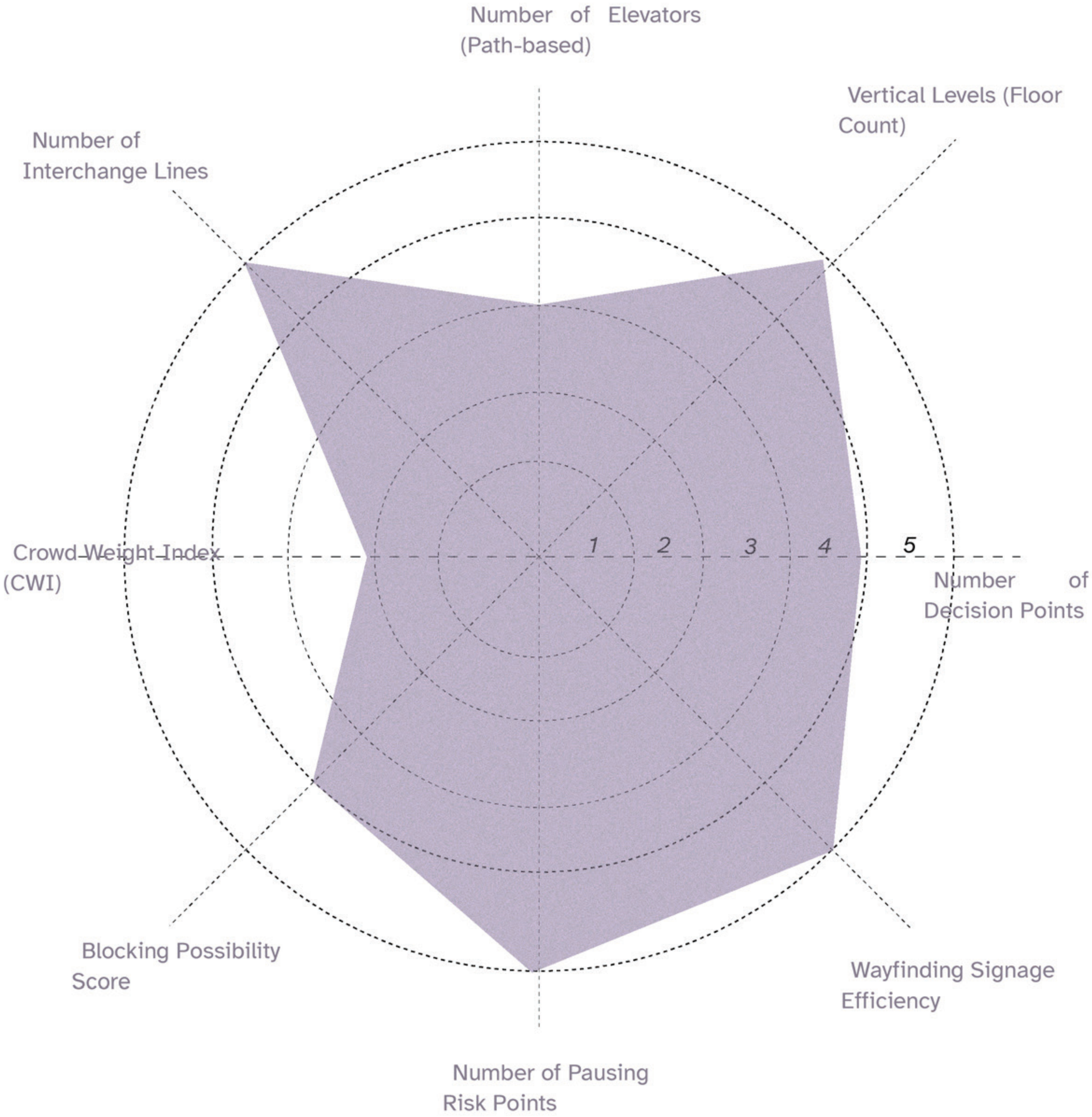
This custom-designed metric evaluates the pressure on accessibility infrastructure. It calculates the ratio between annual station footfall and the number of accessibility facilities (lifts, step-free gates, and assistance points), estimating average crowd load per facility.

Dimension8: Number of Interchange Lines

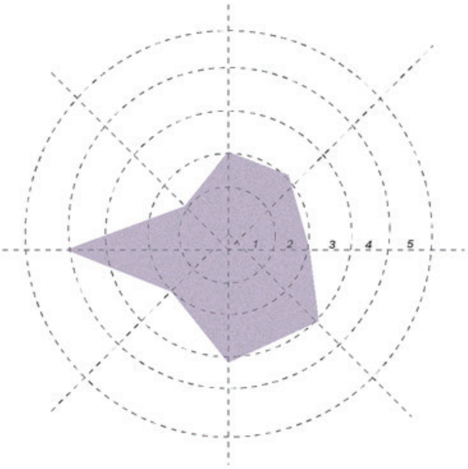
The number of interchange lines indicates a station's internal spatial complexity. More lines typically mean longer, more convoluted paths and a higher risk of pausing or blocking for wheelchair users.

Based on the eight evaluation dimensions, I translated the collected station-level data into radar charts.

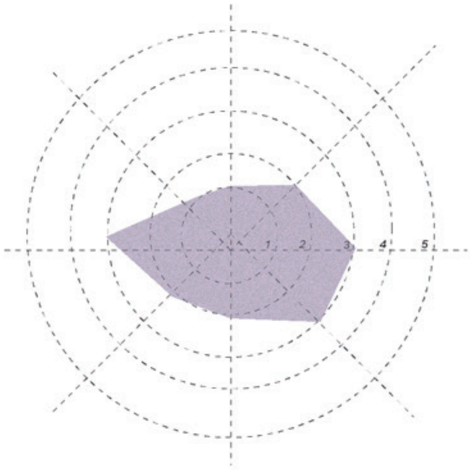
LIVERPOOL STREET STATION RADAR CHART



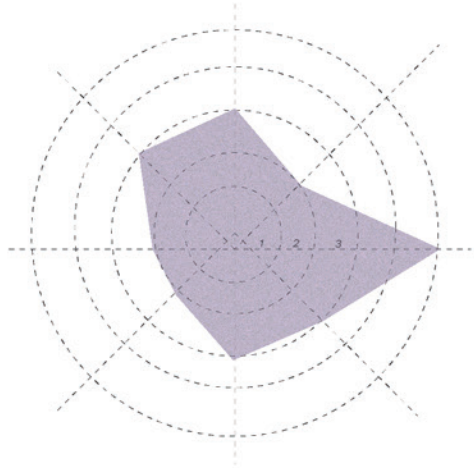
Figures 9-10 Present the example of the radar chart for stations on the Elizabeth Line ,including Liverpool street, Abbey Wood to Hanwell, the complete radar chart will be displayed in the portfolio. Source: Author, 2025.



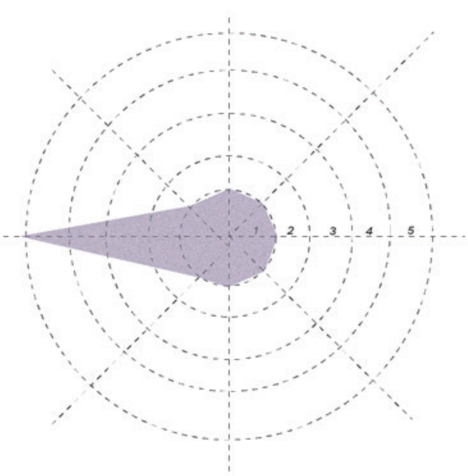
Abbey Wood



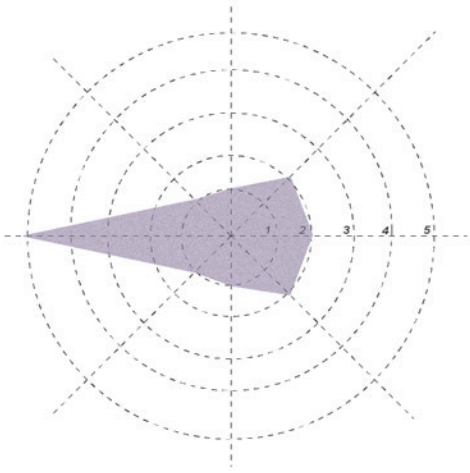
Acton Main line



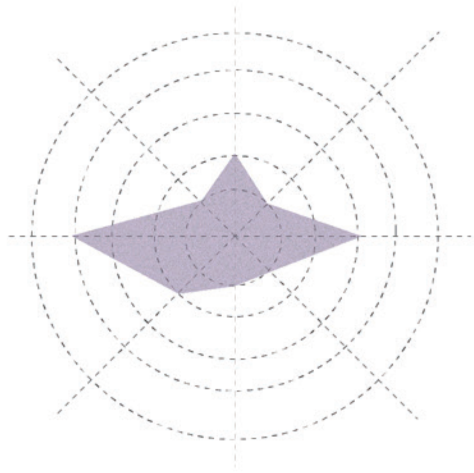
Bond Street



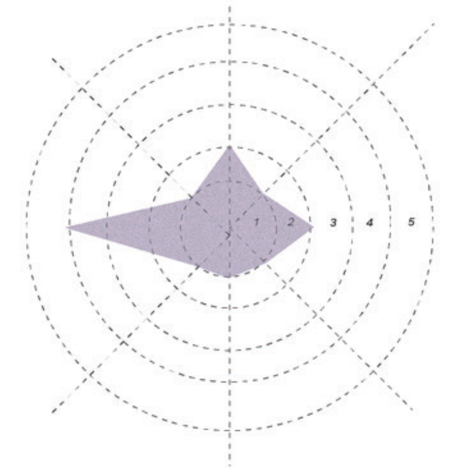
Brentwood



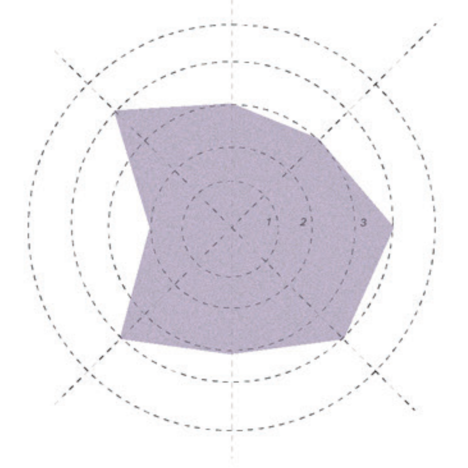
Chadwell Heath



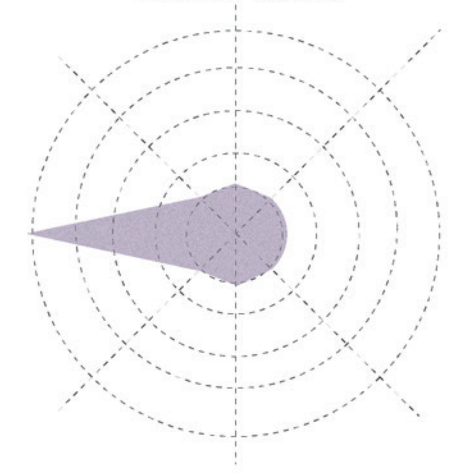
Custom House



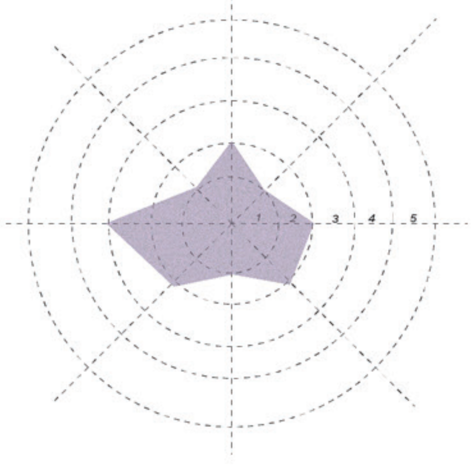
Ealing Broadway



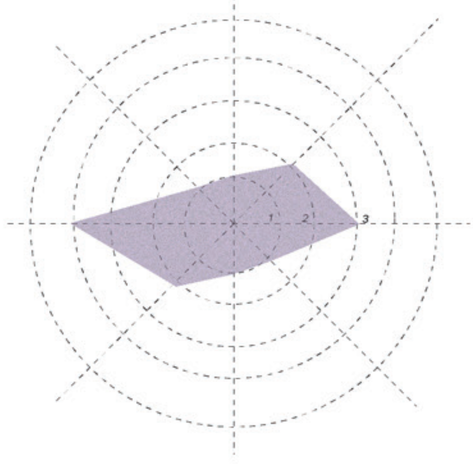
Farringdon



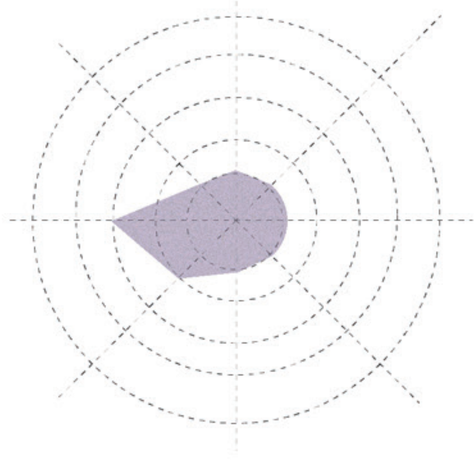
Forest Gate



Gidea Park



Goodmayes



Hanwell

3.4. How to address the Simulating Travel

3.4.1 Selection of Simulated Journey Sites

Based on the radar chart analysis results, this thesis selected Liverpool Street Station, Stratford Station, and Canary Wharf Station as the representative stations for the simulated travel routes. Figure 11 illustrates the route design for the simulated journeys at these stations.

Liverpool Street Station scored highly across all eight radar chart dimensions. It has a complex internal structure, many lift transfers, and a significant load on accessibility infrastructure. It is the most representative complex station on the Elizabeth Line.

The study focuses on the Elizabeth and Jubilee lines, so the simulated journeys must include interchange conditions. Stratford Station and Canary Wharf Station are interchange points between the two lines, making them appropriate for simulation.

Stratford Station is also rated highly on the radar chart. It involves multiple lift transfers and a high level of spatial complexity, making it a representative case.

Although the radar chart scores for Canary Wharf Station are moderate, the interchange between the Jubilee and Elizabeth Lines requires a detour through the Overground section, involving a walking distance of approximately 350 metres. This gives the station a unique infrastructural challenge.

These three stations were selected as the core simulation sites for this research for the following reasons.

3.4.2 Simulating travel time and data

Based on the earlier mapping results, I divided the simulated travel route into five travel states. I recorded the time of arrival at each key node during every simulation.

This thesis conducted nine simulated journeys, following the principles below.

·A manual (non-electric) wheelchair of the same model was used throughout;

·The same simulated traveller performed all journeys.

·The same entrance and exit points were used at each station, and pre-selected lifts were followed.

·Transfer paths were fixed in advance.

·A DJI Pocket 3 camera was mounted to the front of the wheelchair to record the whole journey.

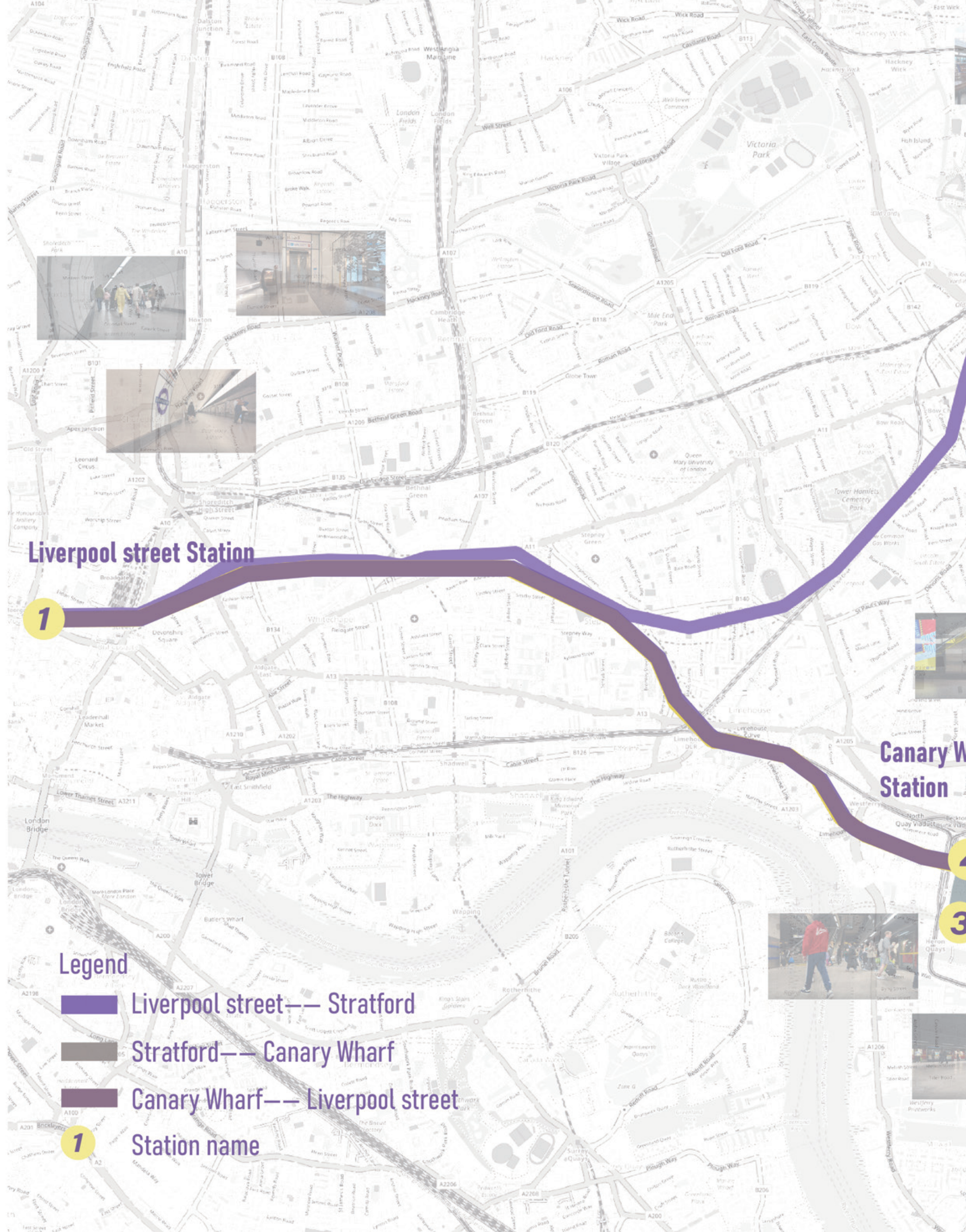
·A stopwatch and iPad were used to manually document the arrival time at each state node (to the precision of “xx mins xx secs”).

The research accounted for differences in passenger volume across periods to control for temporal variation. All simulations were conducted consistently, with variations across peak and off-peak conditions.

The simulation period ran from 1 May to 6 May 2025, covering nine complete simulated journeys.

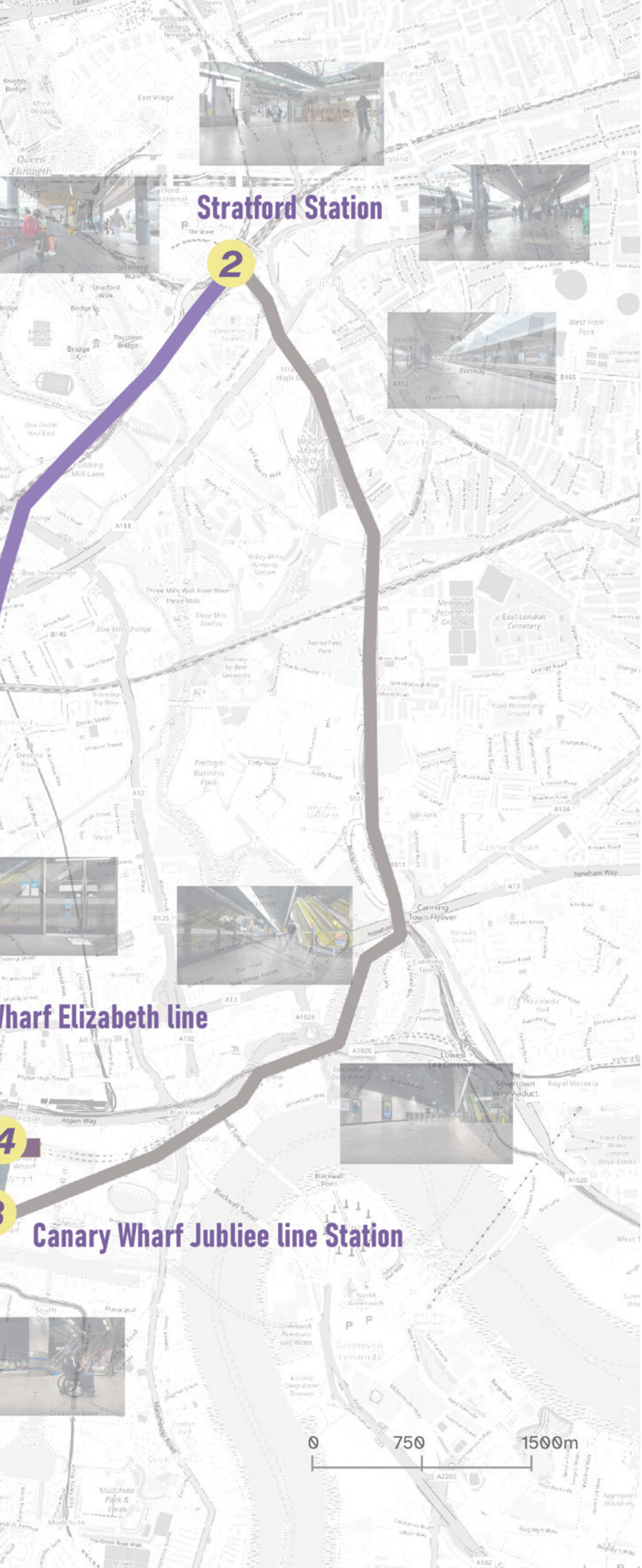
Figure 12-15 shows how I simulated traveling.

SIMULATED JOURNEYS ROUTE



Legend

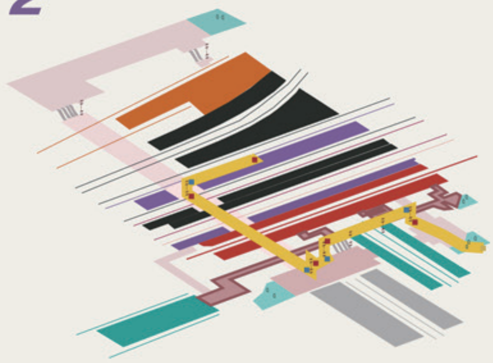
- Liverpool street—— Stratford
- Stratford—— Canary Wharf
- Canary Wharf—— Liverpool street
- 1 Station name



1

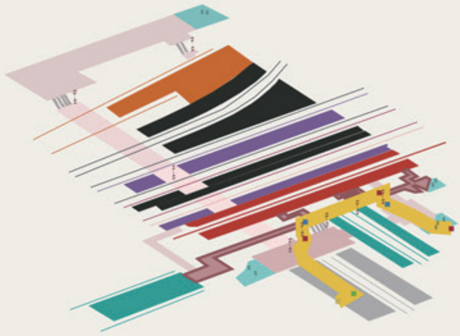
Liverpool street Station
Entrace-Elizabeth train

2



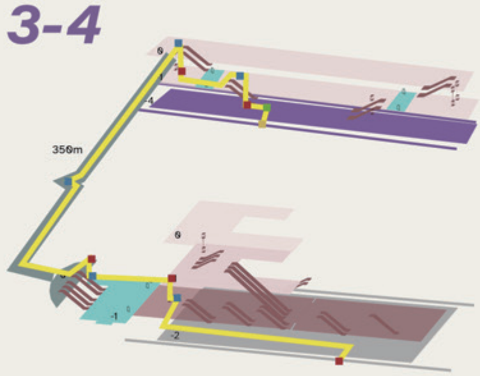
Elizabeth train-Stratford
Station Exit

2-3



*Stratford Station
Entrance-Jubilee train*

3-4



*Canary Wharf Jubliee train-
Canary Wharf Elizabeth train*

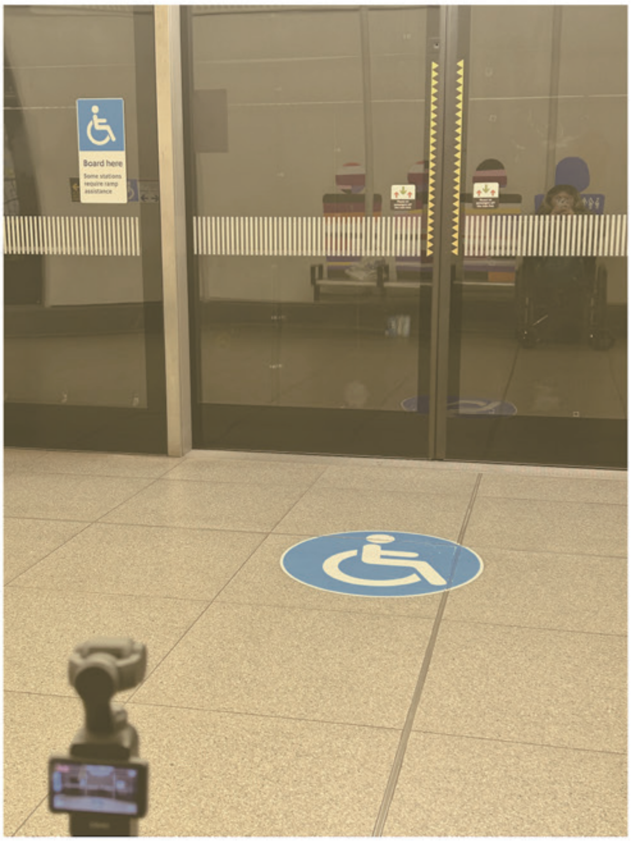


Figure 12-15:
Simulated journey pictures
Source: Author, 2025.


OSPREY

3.4.3 Researcher Role and Identity of the Simulated Traveller

As the researcher is not a wheelchair user, this study approached the simulation stage through the combined methodological lens of phenomenology and Crip Time, employing two distinct travel modes to approximate the experience of wheelchair users navigating the underground system.

Mode A: Wheelchair Push Simulation (Researcher Push)

In this mode, the researcher manually pushed an unoccupied wheelchair along a predefined route. This method enabled consistent control over movement speed while reducing external interference (e.g., unsolicited assistance). It also simulates the travel rhythms of powered wheelchair users or wheelchair users accompanied by carers, emphasising maintaining a steady pace.

Mode B: Wheelchair Ride Simulation (Researcher Ride)

In this mode, the researcher physically sat in the wheelchair and completed the same route, either through self-propulsion or assisted movement.

Given the documented physical strain associated with manual wheelchair use (Ebrahimi, A., et al, 2016), this approach placed greater emphasis on embodied perception, allowing the researcher to engage more directly with the physical fatigue and systemic exclusion often encountered by wheelchair users in transit environments.

In this study, the two modes of travelling were alternated at different times of day and recorded in the experiment report for each round of the experiment. Video and time data were recorded using the same equipment. The methodological design was not intended to replace the real experiences of wheelchair users travelling on the metro, but rather to reflect on the time barriers disabled people face daily from different perspectives (wheelchair users, wheelchair pushers, and experiment recorders).

3.5 Ethical Considerations

This research follows basic ethical principles throughout the design and practice, especially when simulating wheelchair user journeys. The study also reflects on the researcher's identity as a non-wheelchair user.

As explained in Section 3.1, this research is based on phenomenology and Crip Theory, which both see bodily experience not only as something to observe, but also as a way to understand social systems. In this context, I used my own body to simulate wheelchair journeys and to experience time barriers and interruptions in movement.

However, this study does not claim to replace or represent the real experiences of wheelchair users. Instead, it uses simulation to highlight problems such as time barriers and rhythmic inequality in the transport system.

Although I am not a wheelchair user, I have long-term experience related to wheelchair life. I have lived with my grandmother, who has used a wheelchair for over 40 years, for more than 20 years. I have helped her daily and understand the physical and social barriers she faces. I also asked for her opinions and experiences during this research, but I did not include her as a research subject or participant.

All data was collected only in public areas of the TfL transport system. No personal images or behaviours of other people were recorded. The video data was only used to study the route and infrastructure performance.

This study does not involve interviews or hidden data collection. All recordings were made using my devices, and I wrote notes immediately after each simulation. I handle the data only and store it securely. All data used follows proper data protection rules.

Chapter 4: Simulating Travel in the Underground

In this chapter, I will analyse the process of the nine simulated journeys and identify the time barriers that appeared during these travels. I will then systematically categorise these barriers to better understand the types of delays and difficulties wheelchair users may face in the underground system.

4.1 Recording and analysis of simulated travels

This section will discuss the entire simulated travel route in five subsections.

The journey is divided as follows:

1. Liverpool Street Station entrance → Elizabeth Line train boarding

2. Elizabeth Line train → Stratford Station exit

3. Stratford entrance → Canary Wharf (Jubilee Line exit)

4. Canary Wharf (Jubilee Line exit) → Canary Wharf (Elizabeth Line train)

5. Elizabeth Line train → Liverpool Street Station exit

Route 1: Liverpool Street Station Entrance → Elizabeth Line Boarding Area

This section of the journey starts at the entrance to Liverpool Street Station and ends at the boarding area of the Elizabeth Line (Figure. 16 shows the route and its structure). It was generally smooth during the simulation, with no lift failures or rerouting needed.

TfL estimates the journey time to be 7 minutes, but in all nine simulations, the actual travel time was around 11 minutes.

This shows an apparent inaccuracy in TfL's official step-free travel time prediction for wheelchair users.

Observed Time Barriers:

1. Lift Wait Time During Peak Hours

During off-peak hours, I could usually use the lifts without waiting. However, during the morning peak on 6 May and 7 May, I experienced a 4-minute wait at the first lift (State 2).

This lift can hold only two wheelchair users or prams at a time and is the only lift available to access both the mainline and Underground stations from the street level.

This creates a bottleneck and results in forced pausing, caused by limited lift capacity rather than mechanical failure.

2. Lift Congestion

A similar issue occurred at the third lift (State 6) on 6 May, where waiting times were again longer than average.

3. Distance to the Boarding Area and Missed Train. Another issue was the distance between the lift and the boarding zone on the Elizabeth Line platform. The step-free boarding area is typically located near Carriage 5, and not all trains heading to Stratford arrive at regular intervals.

On May 1 and 3, although I arrived at the platform just as the train arrived, I missed boarding because the accessible area was too far to reach in time.

This added around 7 minutes of extra waiting. In contrast, during the 7 PM simulation on 1 May, the train had just arrived as I reached the boarding area, and the total journey time stayed within 11 minutes.

Figure. 16 shows Liverpool Street Station Entrance → Elizabeth Line Boarding Area, Area route and simulated travel records.

Summary of Time Barriers Identified :

1. Lift bottlenecks due to limited capacity, especially during peak hours.

2. The long walking distance between the lift and the step-free boarding zone leads to missed trains and delays.

These barriers were not caused by a lack of infrastructure but by inefficient layout and accessibility design.

This confirms that time barriers still exist in daily travel, even on a "fully step-free line" like the Elizabeth Line.

Figure 17:
Waiting for lift in Liverpool Street Station
Source: Author, 1/May/ 2025.

Route 2: Elizabeth Line Train → Stratford Station Exit

This journey section starts at the Elizabeth Line train at Stratford Station, using four lifts to reach the station's main exit.

TfL estimates this route to take 7 minutes, but the actual travel time was usually around 11 minutes across all nine simulated journeys.

Observed Time Barriers

1. Lift Out of Service (5 May – Bank Holiday)

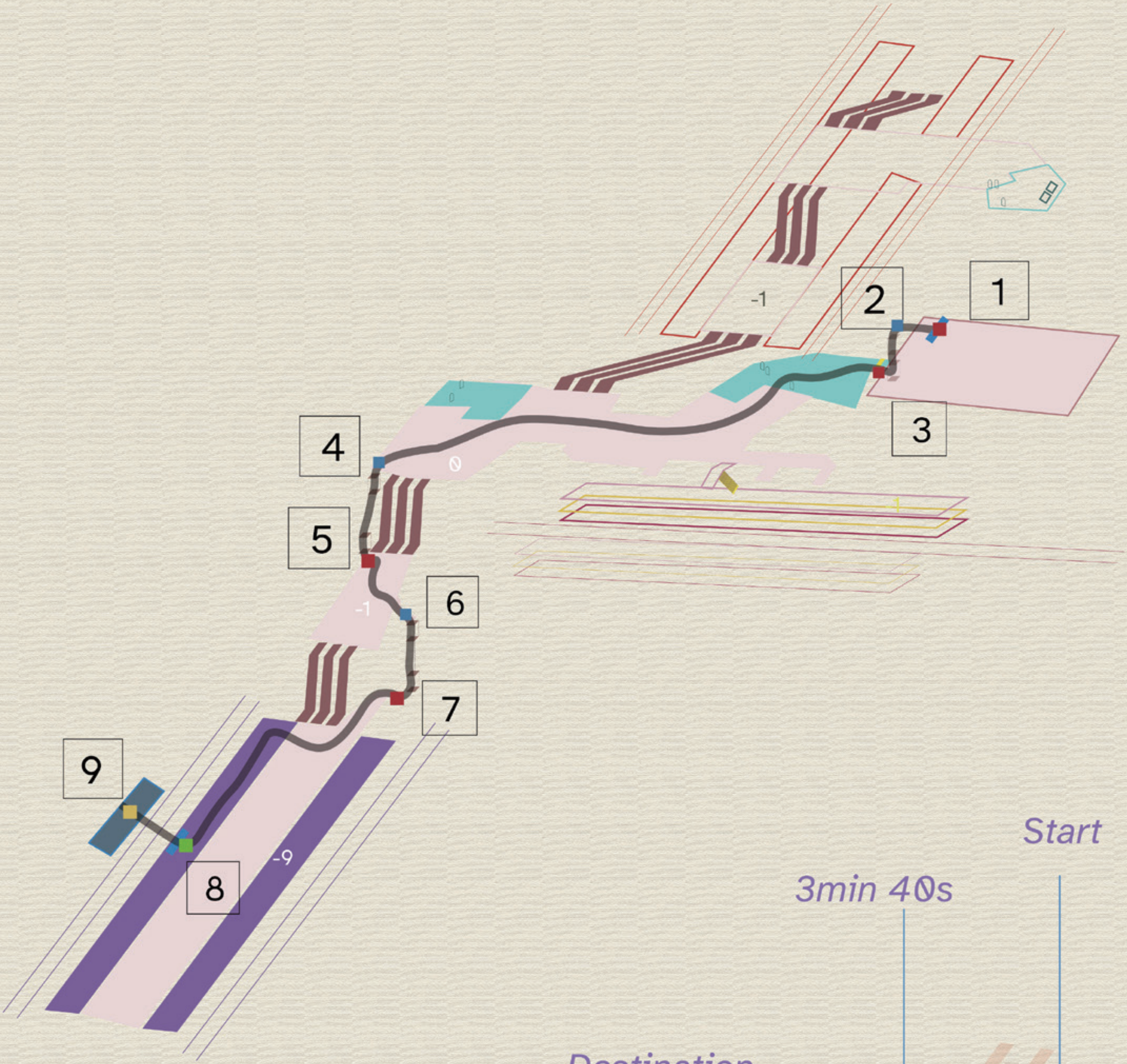
During the simulation on 5 May (Bank Holiday), two of the four lifts at Stratford Station were out of service, and one of the main exits was closed (see Figure 18-21).

This significantly changed how people exited the station. Although there were still working lifts, wheelchair users had to take a longer alternative route.

I observed a wheelchair user ahead of me who, after discovering the main exit was closed, was forced to reroute, which added about 10 minutes to their journey.

2. Lift Capacity Issues

ROUTE1



HOW TO READ

Legend

- 1 State
- Navigating
- Reaching
- Approaching
- Pausing

1/MAY/THU
9 AM.
Pushing the wheelchair
0.00
1.39
3.40
3.01
5.16
6.47
8.08
9.26
18.04
11.54
Weekday
Peak time
1/MAY/THU
7 PM
Sitting in the wheelchair
0.00
1.41
4.04
3.17
5.16
7.18
8.23
9.04
13.03
11.10
Weekday
OFF-Peak time
2/MAY/THU
7 AM
Sitting in the wheelchair
Weekday
Peak time
2/MAY/FRI
7 PM.
Pushing the wheelchair
0.00
0.54
3.50
2.04
5.39
7.08
8.23
9.12
11.35
11.15
Weekday
Peak time
3/MAY/SAT
12 PM.
Pushing the wheelchair
0.00
1.39
3.40
3.01
5.16
6.47
8.08
9.26
18.04
11.54
Weekend
OFF-Peak time
4/MAY/SUN
12 PM.
Pushing the wheelchair
Weekend
OFF-Peak time
5/MAY/MON
9 AM.
Sitting in the wheelchair
0.00
1.15
3.58
3.19
4.53
6.27
7.25
8.59
17.04
11.25
Bank Holiday
OFF-Peak time
6/MAY/TUE
8 AM.
Pushing the wheelchair
0.00
1.24
3.50
3.01
5.24
6.48
8.25
9.54
15.03
13.26
Weekday
Peak time
7/MAY/WED
8 AM.
Sitting in the wheelchair
0.00
2.10
4.25
3.56
6.18
7.47
9.12
10.58
16.04
13.23
Weekday
Peak time

At State 4 (the second lift along the route), the lift was old and small, and it could only hold one wheelchair or one pushchair at a time. This created a long queue, especially during busy periods.

3. Platform-to-train boarding issue

Although Stratford is listed as step-free from street to platform, boarding and exiting the train require assistance, such as using a ramp or help from other passengers or staff. If assistance is not immediately available, this can cause additional delays.

Figure 18-21:
Two lifts in Stratford Station were out of service, and one of the main exits was closed
Source: Author, 5/May/2025.

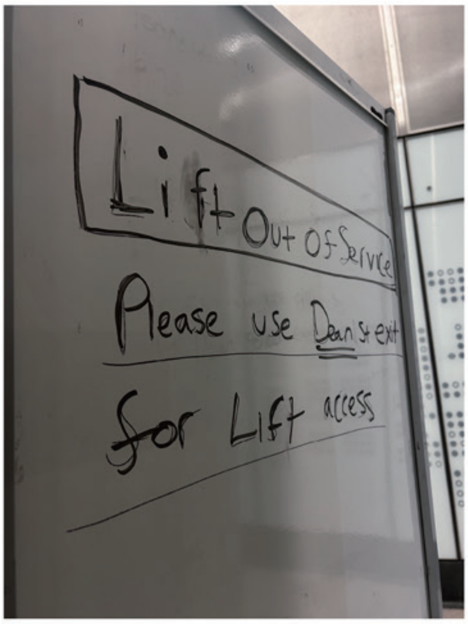
Summary of Time Barriers Identified in Route 2:

- Lift failure and exit closure, leading to forced rerouting and longer travel time for wheelchair users.

- Lift and exit capacity limits, causing waiting delays, especially during high passenger flow.

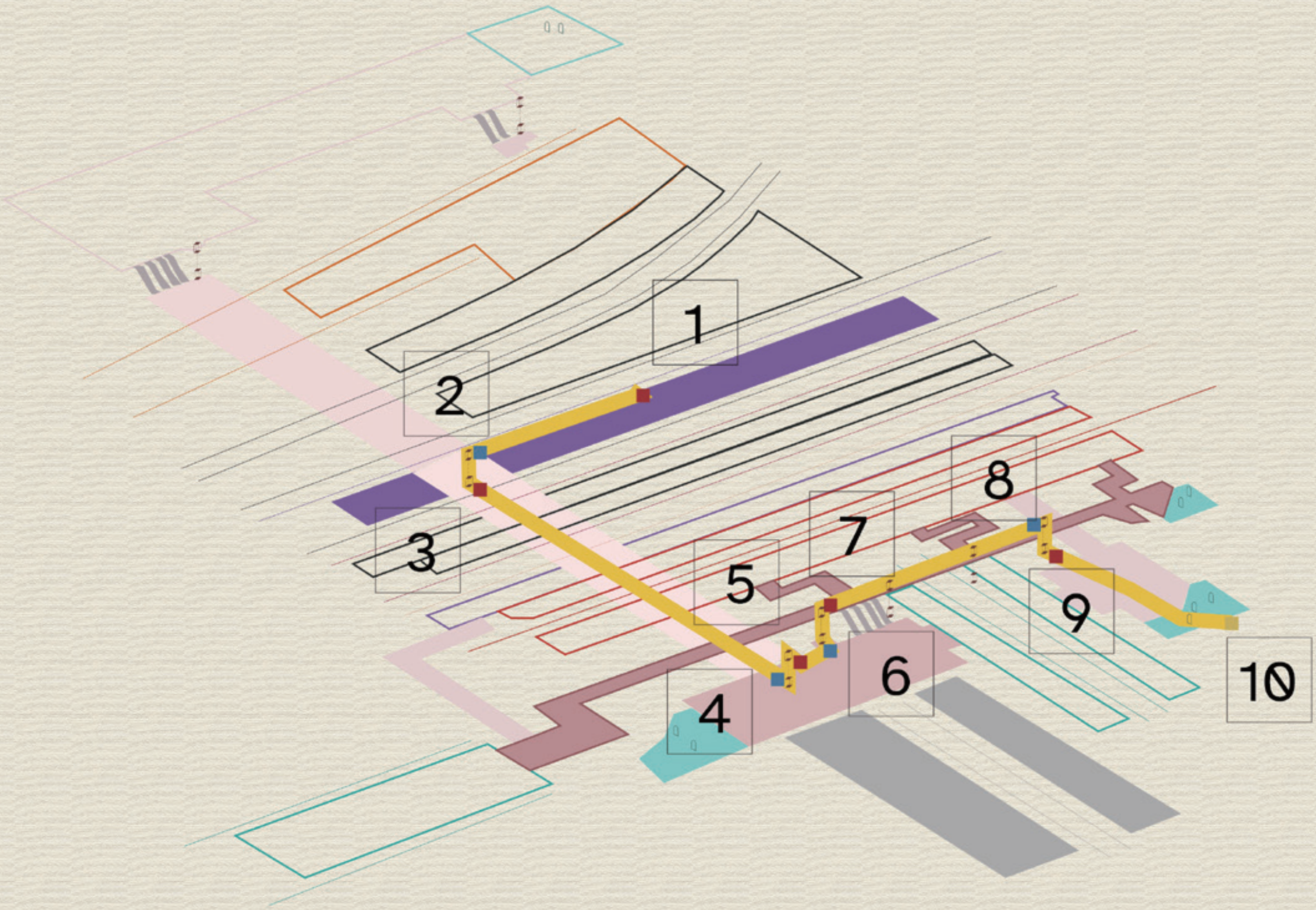
- Reliance on assistance for safe boarding or alighting adds uncertainty and waiting time.

Figure 22 shows Elizabeth Line Train → Stratford Station Exit route and a simulated travel record.



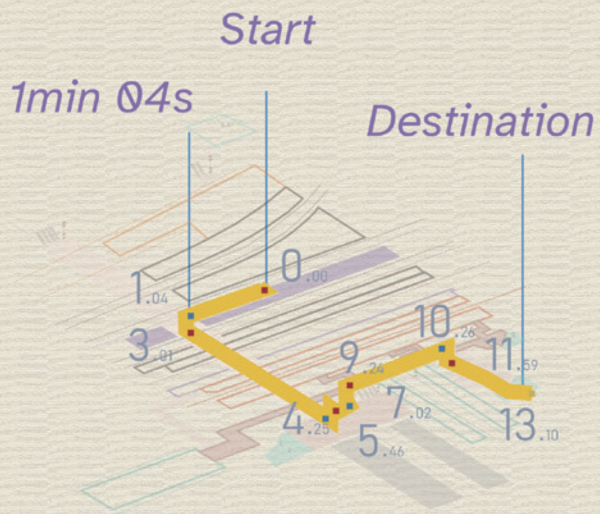
These time barriers again show that infrastructure presence does not equal accessibility. Even at a "step-free" station like Stratford, system failures and poor capacity planning can create significant time delays for wheelchair users.

ROUTE2

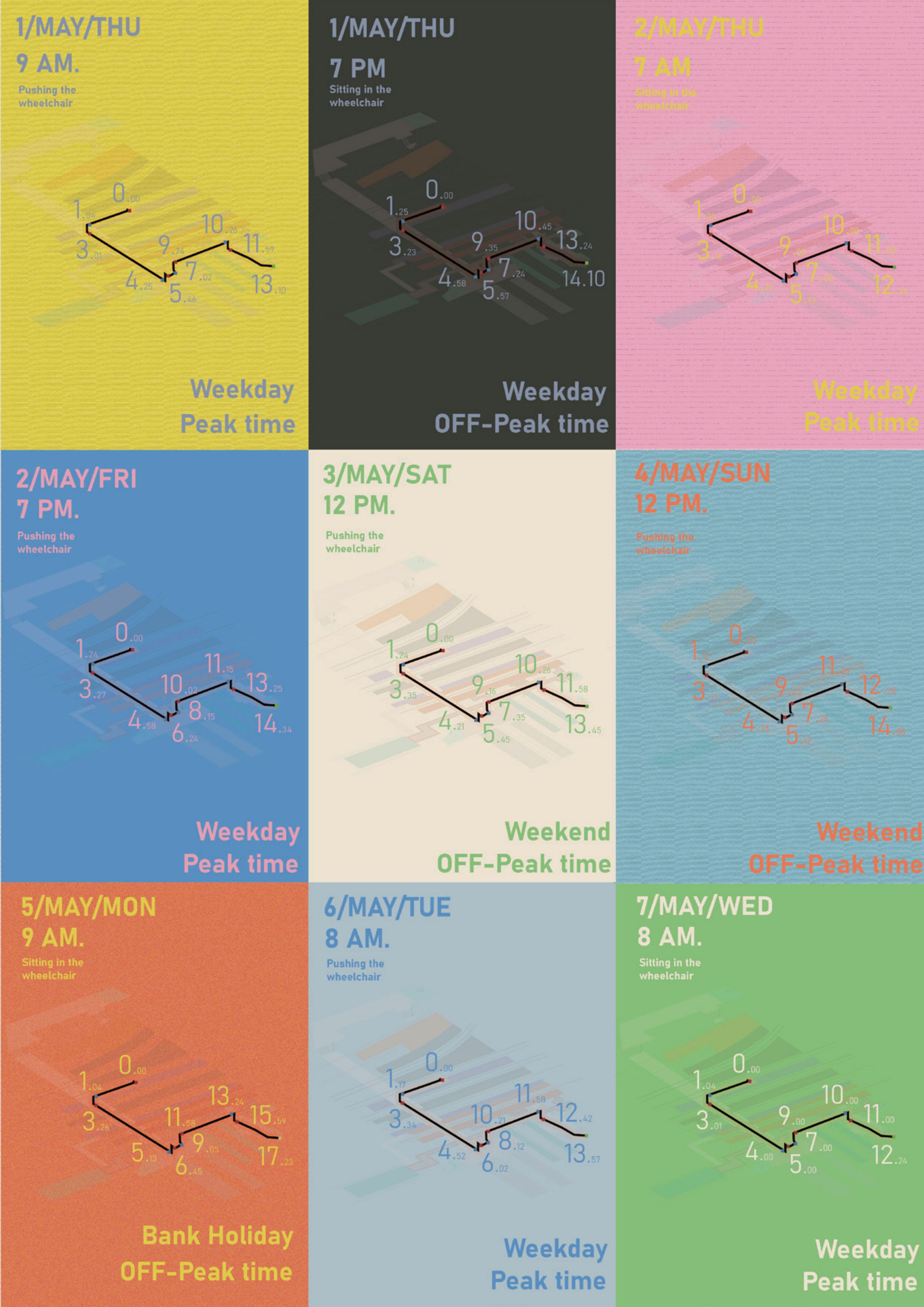


Legend

- 1 State
- Navigating
- Reaching
- Approaching
- Pausing



HOW TO READ



1/MAY/THU
9 AM.
Pushing the wheelchair
0.00 1.04 3.01 4.25 5.46 7.02 9.24 10.26 11.59 13.10
Weekday
Peak time
1/MAY/THU
7 PM
Sitting in the wheelchair
0.00 1.25 3.23 4.58 5.57 7.24 9.35 10.45 13.24 14.10
Weekday
OFF-Peak time
2/MAY/THU
7 AM
Sitting in the wheelchair
Weekday
Peak time
2/MAY/FRI
7 PM.
Pushing the wheelchair
0.00 1.24 3.27 4.58 6.24 8.15 10.02 11.15 13.25 14.34
Weekday
Peak time
3/MAY/SAT
12 PM.
Pushing the wheelchair
0.00 1.24 3.35 4.21 5.45 7.35 9.16 10.26 11.58 13.45
Weekend
OFF-Peak time
4/MAY/SUN
12 PM.
Pushing the wheelchair
Weekend
OFF-Peak time
5/MAY/MON
9 AM.
Sitting in the wheelchair
0.00 1.04 3.26 5.13 6.45 9.05 11.58 13.24 15.59 17.23
Bank Holiday
OFF-Peak time
6/MAY/TUE
8 AM.
Pushing the wheelchair
0.00 1.17 3.34 4.52 6.02 8.12 10.21 11.58 12.42 13.57
Weekday
Peak time
7/MAY/WED
8 AM.
Sitting in the wheelchair
0.00 1.04 3.01 4.00 5.00 7.00 9.00 10.00 11.00 12.24
Weekday
Peak time

Route 3: Stratford Station Entrance → Jubilee Train Boarding Area

This journey section starts at Stratford Station's main entrance, uses two lifts, and ends at Platform 14, where passengers board the Jubilee Line train towards Canary Wharf.

Observed Time Barriers

• 1. Lift Out of Service and Rerouting (5 May – Bank Holiday)

Similar to the previous route, the simulation on 5 May was affected by lift outages, which forced a longer detour and added waiting time.

• 2. Lack of Clear Accessibility Signage on the Jubilee Platform

After arriving at the Jubilee Line platform, no clear accessibility signs were visible. As a result, in every simulation, I had to walk towards the approximate location of the step-free boarding area and wait there.

Once the train arrived, I had to adjust my position again depending on where the accessible carriage stopped.

Figure 23 shows how the platform lacks clear signage for step-free boarding. This issue caused additional time spent searching for the correct location.

Figure 23
There is no signs in Stratford Jubilee station
Source: Author, 2/May/2025.

Summary of Time Barriers Identified in Route 3:

- Rerouting and waiting caused by out-of-service lifts.

- No visible accessibility signage, leading to extra time spent locating step-free boarding areas on the platform.

This part of the journey shows how missing or unclear visual information can become a real-time barrier, especially with infrastructure failures. Even when physical access exists, navigational uncertainty adds stress and delay for wheelchair users.

Figure 24 shows Stratford Station Entrance → Jubilee Train Boarding Area route and a simulated travel record.

Route 4: Canary Wharf (Jubilee Exit) → Canary Wharf (Elizabeth Line Boarding)

This segment starts from the Jubilee Line platform at Canary Wharf, where I took two lifts to reach the street-level exit.

Then, I crossed through the One Canada Square building to reach the entrance of Canary Wharf Elizabeth Line station.

After that, I used two more lifts to reach the Elizabeth Line platform and boarded the Elizabeth Line train.

This route involved an out-of-station transfer, which meant more state points and a more complex journey.

TfL estimates it takes 11 minutes to transfer from the Jubilee Line to the Elizabeth Line platform at Canary Wharf. However, I encountered significant time barriers during multiple simulations between 2 May and 6

May. Most notably, the lift at the Jubilee Line platform was out of service, which caused significant disruptions.

On 2 May, when I reached the lift, I found it was not working. I then tried to find a staff member, but no one was on the platform.

Although the signage mentioned an emergency lift, I could not locate it alone.

Since I had an accompanying person during this journey, we simulated an alternative method[5] that some wheelchair users use when lifts are unavailable — using the escalator with assistance.

This strategy reflects what Piepzna-Samarasinha (2022) describes as a disabled person's ability to "reorganise every aspect of daily life" in response to inaccessible infrastructure.

Figure25 shows the out of service in Canary Wharf Station(Jubilee platform)

Figure 25
Out of service lift in Canary wharf station
Source: Author, 2/May/2025.

During the 4 May simulation, heavy passenger flow also made wheelchair users' lives difficult. While travelling, I met another wheelchair user stuck in front of the in front of the out-of-service lift.

Together, we used the Help Point to ask for assistance, but the station staff responded as follows:

***Staff*: How can I help you?**

***Users*: I am using a wheelchair, and I want to go upstairs.**

***Staff*: The lift will not be working for five days.**

***Users*: For five days? I want to go to the Elizabeth line, so how can I get there?**

***Staff*: Where are you going for the Elizabeth line?**

***Users*: Sorry?**

***Staff*: Which station would you like to go to?**

***Users*: Liverpool Street**

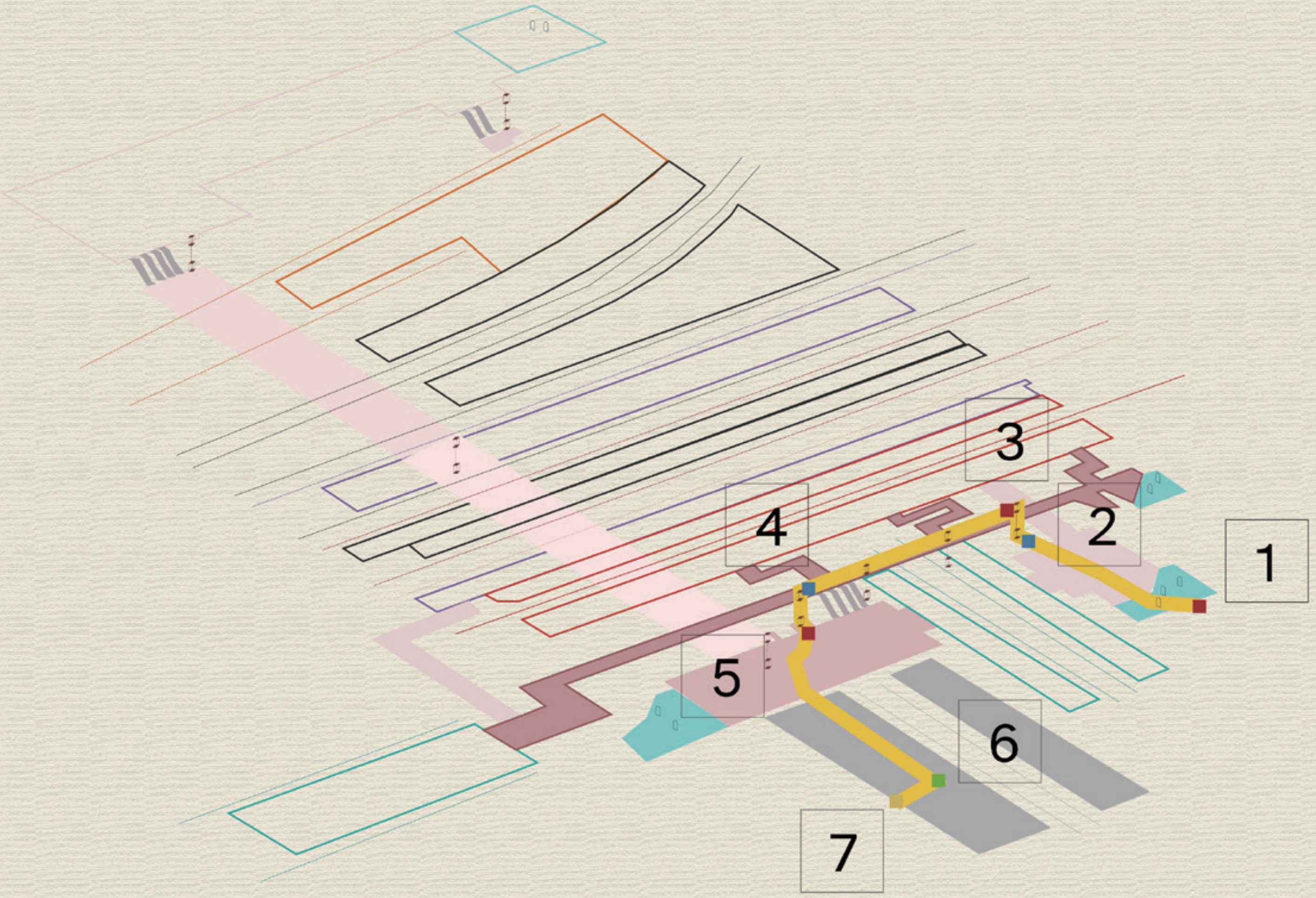
***Staff*: So what you need to do is go to platform 2 (to Stratford direction), take the train to Stratford**

***Users*: I'm sorry, sir. We have a wheelchair, and the lift is out of service, so we cannot go upstairs now.**

***Staff*: Not here, so go back to platform two and go to Stratford.**

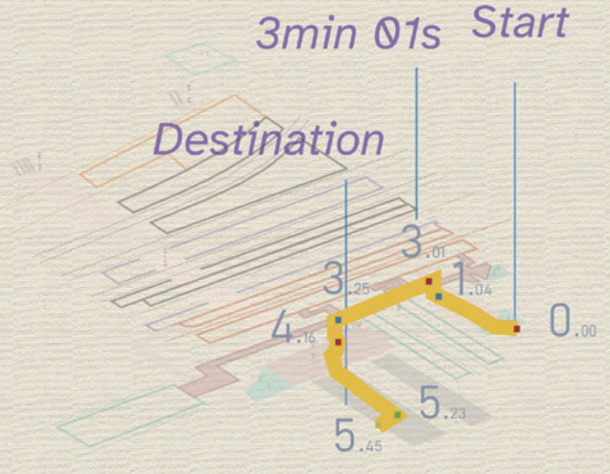
Footnote 5: This method was used during the simulation because an assistant was present. It reflects a commonly used alternative strategy by wheelchair users when lifts are unavailable

ROUTE3

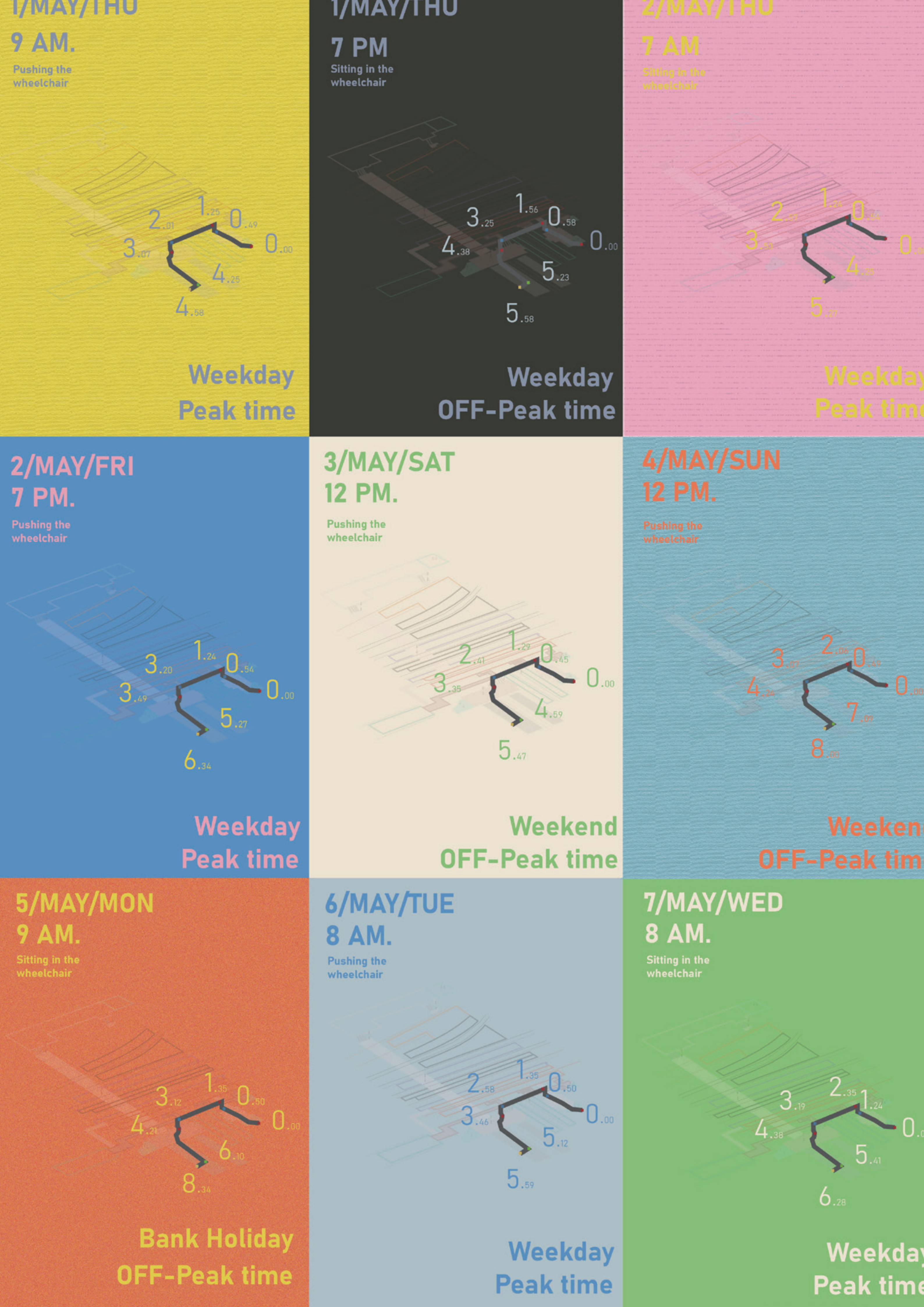


Legend

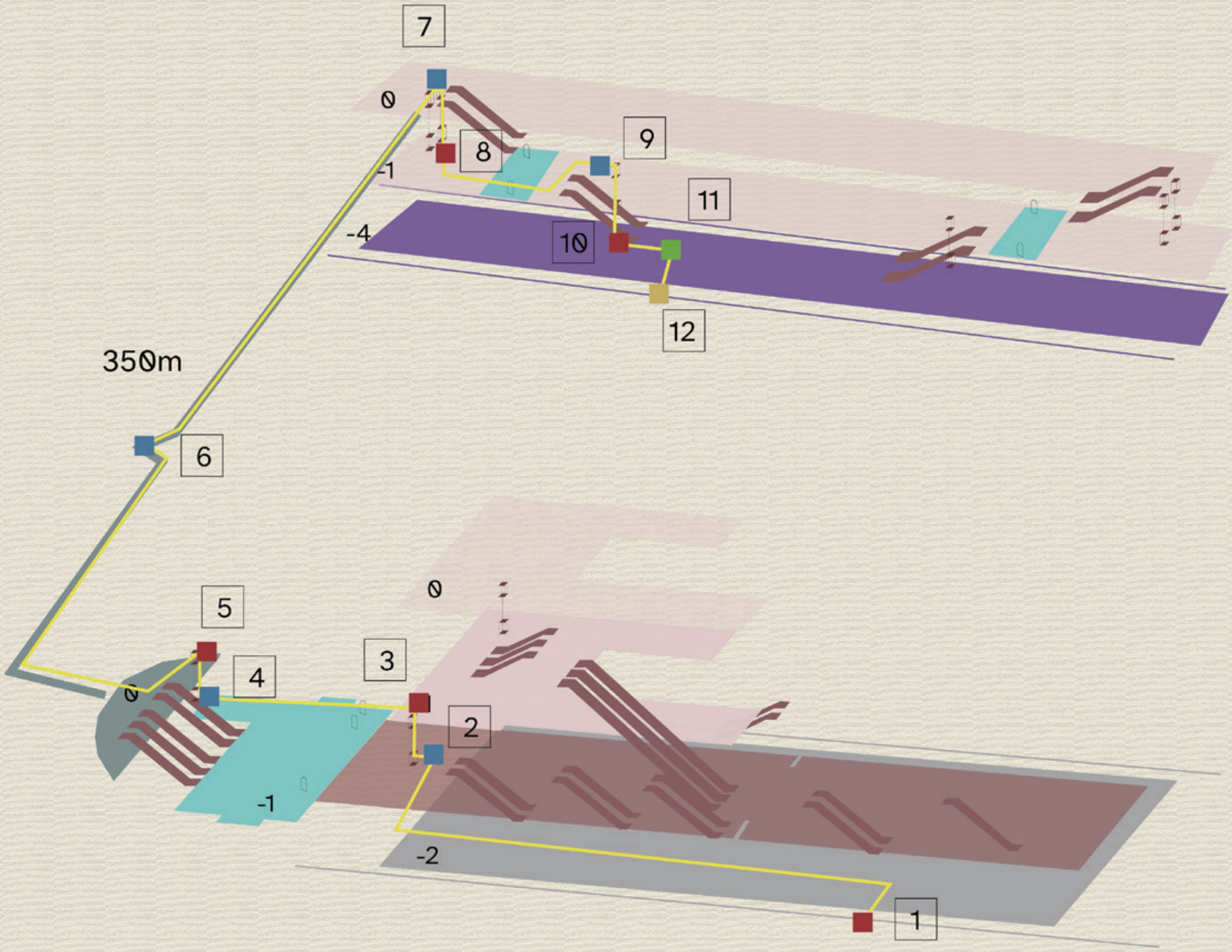
- 1 State
- Navigating
- Reaching
- Approaching
- Pausing

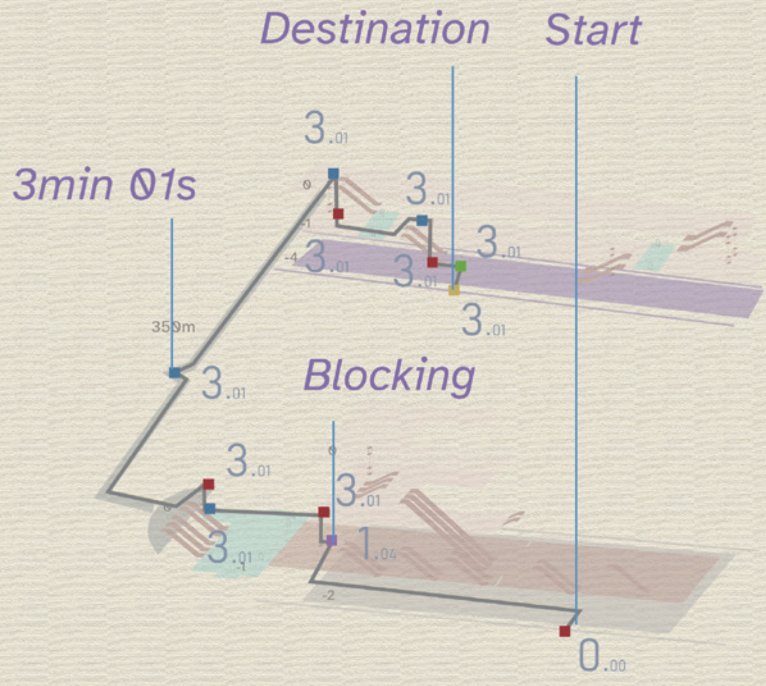


HOW TO READ


1/MAY/THU
9 AM.
Pushing the wheelchair
2.01 1.25 0.49 0.00 3.07 4.25 4.58
Weekday
Peak time
1/MAY/THU
7 PM
Sitting in the wheelchair
3.25 1.56 0.58 0.00 4.38 5.23 5.58
Weekday
OFF-Peak time
2/MAY/THU
7 AM
Sitting in the wheelchair
Weekda
Peak tim
2/MAY/FRI
7 PM.
Pushing the wheelchair
3.20 1.24 0.54 0.00 3.49 5.27 6.34
Weekday
Peak time
3/MAY/SAT
12 PM.
Pushing the wheelchair
2.41 1.29 0.45 0.00 3.35 4.59 5.47
Weekend
OFF-Peak time
4/MAY/SUN
12 PM.
Pushing the wheelchair
Weeken
OFF-Peak tim
5/MAY/MON
9 AM.
Sitting in the wheelchair
3.12 1.35 0.50 0.00 4.21 6.10 8.34
Bank Holiday
OFF-Peak time
6/MAY/TUE
8 AM.
Pushing the wheelchair
2.58 1.35 0.50 0.00 3.46 5.12 5.59
Weekday
Peak time
7/MAY/WED
8 AM.
Sitting in the wheelchair
3.19 2.35 1.24 4.38 5.41 6.28
Weekday
Peak time

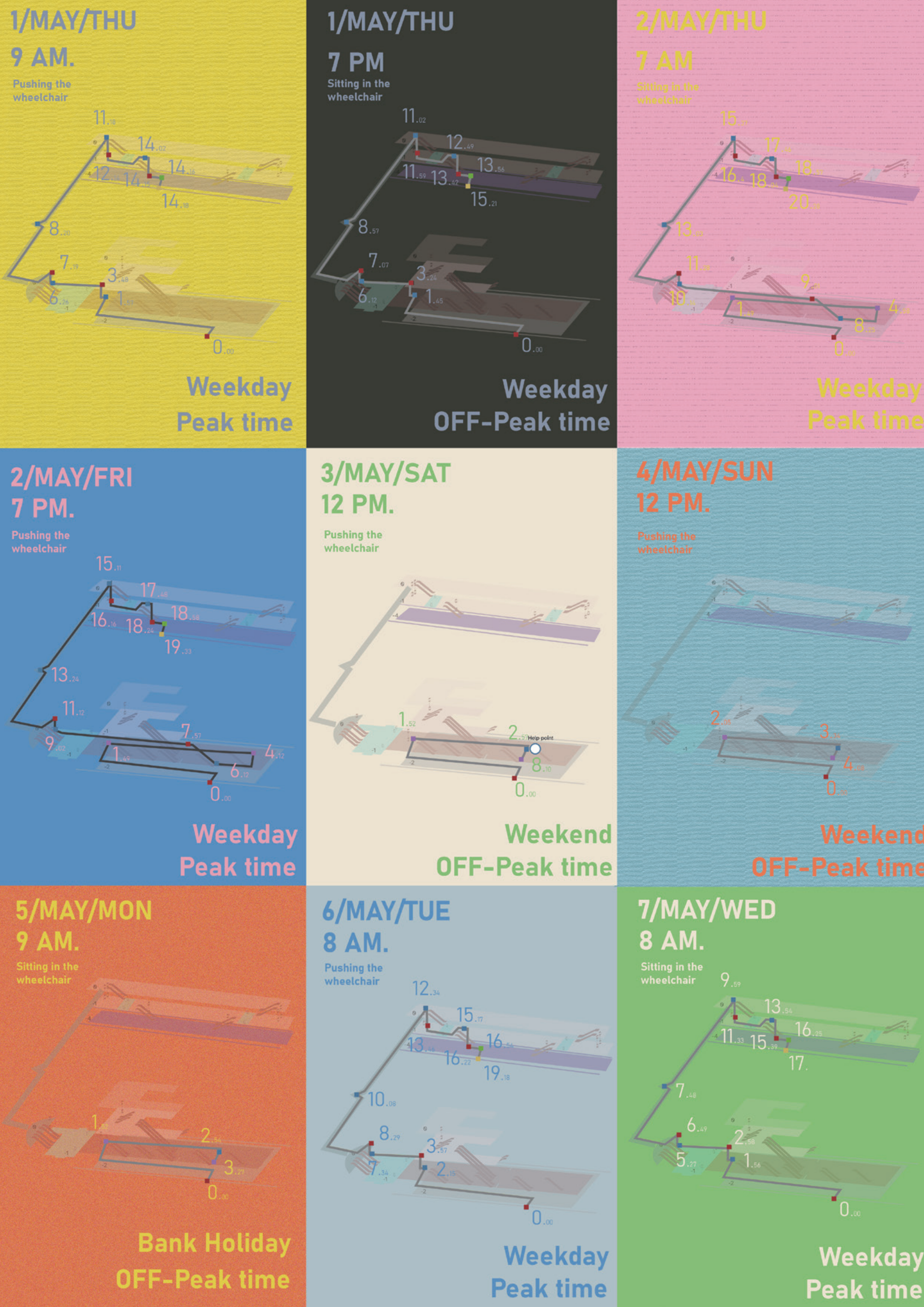
ROUTE4





Legend

- 1 State
- Navigating
- Reaching
- Approaching
- Pausing
- Blocking


1/MAY/THU
9 AM.
Pushing the wheelchair
Weekday
Peak time
1/MAY/THU
7 PM
Sitting in the wheelchair
Weekday
OFF-Peak time
2/MAY/THU
7 AM
Sitting in the wheelchair
Weekday
Peak time
2/MAY/FRI
7 PM.
Pushing the wheelchair
Weekday
Peak time
3/MAY/SAT
12 PM.
Pushing the wheelchair
Help point
Weekend
OFF-Peak time
4/MAY/SUN
12 PM.
Pushing the wheelchair
Weekend
OFF-Peak time
5/MAY/MON
9 AM.
Sitting in the wheelchair
Bank Holiday
OFF-Peak time
6/MAY/TUE
8 AM.
Pushing the wheelchair
Weekday
Peak time
7/MAY/WED
8 AM.
Sitting in the wheelchair
Weekday
Peak time

The wheelchair user eventually chose platform 2 to go to another station. My simulation was also interrupted, as I could not reach the Elizabeth Line platform at Canary Wharf.

Although the Jubilee Station at Canary Wharf has an emergency lift, station staff did not activate it for us or provide on-platform assistance.

In addition, when we got off the Jubilee Line train, there were no signs indicating that the lift was out of service.

The only notice was placed directly at the lift entrance, which led to unnecessary time barriers and rerouting. The lift was not back in operation until 6 May.

It is worth noting that at Canary Wharf Elizabeth Line station, the accessible lift is located at the centre of the platform (see Figure 27). This means wheelchair users have a short and direct path to the step-free boarding area, unlike the longer walking distances required at stations like Liverpool Street.

Based on my review of all underground Elizabeth Line stations, only Paddington and Canary Wharf have lifts in the platform's centre.Most other stations—Bond Street, Tottenham Court Road, Farringdon, Liverpool Street, and Whitechapel—have lifts at either end of the platform.

Summary of Time Barriers Identified

1. The lift's outage caused wheelchair users to interrupt or change their planned routes, resulting in clear time barriers.

2. Until reaching the lift itself, there was no visible warning signage about the lift failure, leading to unnecessary delays and confusion.

Route 5: Canary Wharf (Elizabeth Line Boarding)→ Liverpool Street Station Entrance

This route begins with arriving at the Elizabeth Line platform at Liverpool Street Station. Then, it takes three lifts to reach the station entrance, which is also the starting point of the overall journey.

Overall, this route's travel time and time barrier points were very similar to those in Route 1, so they are not repeated here.

Figure 27:
In Canary Wharf Elizabeth line platform, the lift is closed to the broad area
Source: Author, 3/May/2025.

Across all nine simulated journeys, time barriers were observed in every journey.

Although this study does not include a full control group and was limited in duration due to time constraints, the data still provide a clear foundation for responding to the core research questions.

1. Do wheelchair users experience significant time burdens in the London Underground system? If so, which types of infrastructure contribute most to these delays?

The simulations clearly show that wheelchair users face significant time barriers during underground travel.

These delays are most commonly associatedwith the following types of infrastructure:

- Lifts – including out-of-service lifts, limited lift capacity, and long queues during peak hours
- Long distances between lifts and step-free boarding areas
- Poor signage – especially unclear or missing step-free navigation signs
- Station layouts that require multiple level changes, lengthy detours, or unclear exit routes
- Platform-to-train transitions that rely on assistance or lack boarding ramps

Even on lines officially marked as "fully step-free," these barriers show that time-based accessibility remains a serious challenge.

4.2 Classification and summary of time barriers

Each journey encountered different time barriers in the nine simulated journeys conducted in this research.

To better understand the underlying causes of these barriers, I categorised them into three main types and explained their specific manifestations.

1. Delay-Based Barrier

This type of barrier refers to situations where wheelchair users are forced to wait in place, resulting in pauses and interruptions to their journey. These delays are often caused by long lift waiting times or congestion in narrow pathways due to high passenger volumes.

For example, during peak-time simulations at Liverpool Street Station, I experienced four separate instances of waiting more than two minutes for an accessible lift due to limited capacity. This kind of passive waiting was observed repeatedly across multiple journeys.

2. Detour-Based Barrier

This type of barrier occurs when wheelchair users cannot take a direct route due to poor infrastructure layout, unclear signage, or temporary closure of key pathways. As a result, they are forced to take longer alternative routes or spend additional time searching for a passable path.

For instance, during the simulation at Stratford Station on 5 May, the main lift was out of service, and one of the exits was closed. This required wheelchair users to reroute through a longer, less direct path, adding approximately 10 minutes to the total journey time.

3. Blockage-Based Barrier

This type of barrier refers to situations where wheelchair users encounter complete physical obstructions, making it impossible to proceed along the planned route. Fully out-of-service lifts often cause issues with no available emergency alternatives or the total closure of accessible exits.

For example, during the simulation at Canary Wharf (Jubilee platform) on 4 May, the main lift was entirely out of service, and no emergency lift was available. As a result, it was impossible to complete the route, and the only options were to either return the way I came or seek assistance from others. This created a severe disruption in travel rhythm and, in some cases, led to the failure of the planned journey.

These classifications reveal that the time barriers faced by wheelchair users in the underground system are not merely isolated incidents of delay, but rather part of a multi-dimensional and structural problem.

These barriers not only extend the actual travel time but also place added physical and emotional strain on wheelchair users. More importantly, many of these issues are hidden beneath the surface of official data that focuses on whether accessibility infrastructure has been “completed” or not.

They expose critical weaknesses in infrastructure design, route planning, and operational management within TfL’s accessibility system.

These findings provide substantial evidence for Chapter 5's discussion of time as infrastructure and the more profound inequalities embedded in everyday mobility systems.

4.3 Time barrier Reason analysis:

Based on the classification of time barriers identified across the nine simulated journeys, it is clear that these obstacles are not simply the result of occasional technical failures or staff mistakes. Instead, they point to deeper structural problems and patterns of exclusion embedded within the design and management processes of TfL's accessibility infrastructure.

At present, TfL's understanding of "accessibility" remains primarily focused on whether certain facilities exist and whether they are technically passable. However, this logic fails to account for the temporal dimension of accessible travel—what could be called the temporal performance of infrastructure. Planning, evaluation, or design frameworks do not include key factors such as lift wait times, extended travel paths, and delays caused by poor spatial coordination.

A representative example of this oversight can be found in the newly constructed Elizabeth Line, which is often celebrated for its full step-free coverage. While all stations on the line are technically step-free, the spatial layout of key facilities still creates structural delays. At most central stations, lifts are located at either end of the platform, while the step-free boarding area is usually positioned around Carriage 5—the train's centre. This means wheelchair users must travel across the platform to board or exit, incurring extra physical and temporal effort. Only a few stations, such as Paddington and Canary Wharf, place lifts near the platform centre, resulting in shorter, more efficient routes.

Similar problems are more prevalent in suburban above-ground stations. Although elevators are available, they are often located close to the platform's edge. In contrast, accessible cars are located far to the other side, requiring passengers to detour to get on the train. Such "redundant paths" directly result from the unnecessary extra time spent by wheelchair users, which is not documented or reflected in existing assessment systems.

During my fieldwork, I experienced another problem. On 20 March, I went to the Elizabeth Line platforms at Farringdon Station. At the time, the lift near the Farringdon exit was out of service. After reaching the platform from the step-free carriage in the middle of the train, I found no clear signage or notification about the lift failure. Upon arriving at the lift, I realised it was not operational, forcing me to reroute all the way to the Barbican exit on the opposite end. This unexpected detour added over 10 minutes to the journey.

Such examples reflect a broader issue: TfL's accessibility system lacks an effective information delivery mechanism. While apps like My Journey or TfL offer live updates on transport conditions, in-station environments often fail to provide clear, real-time information at critical points. These gaps disproportionately affect users who cannot rely on smartphones or lack internet access due to poor signal. The absence of accessible, physical information at stations is a source of a time barrier.

These findings allow us to address the second research question:

How are these time barriers related to the design and management logic of the transport infrastructure?

They directly result from limitations in TfL's infrastructure planning, design, and operational management. Furthermore, TfL's current accessibility evaluation system remains primarily structural and static, relying on facility checklists, coverage ratios, and technical specifications. Such indicators cannot reflect the real disruptions, delays, and burdens experienced by users in practice. The failure to systematically include time use and temporal experience into infrastructure logic creates a condition of structural temporal exclusion, which is normalised and rendered invisible in everyday operations. While many time barriers may appear to be technical, they reveal a persistent marginalisation of wheelchair users within transport governance.

This research, therefore, approaches accessibility from a temporal perspective, going beyond conventional physical infrastructure frameworks to reveal how seemingly neutral systems can generate structural inequality over time.

Chapter 5 Discussion

5.1 Reviewing Current Accessibility Infrastructure Policies of TfL

To propose an accessibility infrastructure and operations policy that integrates temporal performance as a key innovation, it is first necessary to examine TfL's current approach to accessibility planning and delivery.

This study adopts a Critical Policy Analysis framework to analyse two key accessibility policy documents released by TfL in 2024: the London Underground Accessible Travel Policy and Making Rail Accessible – Design Standards for the Elizabeth Line.

TfL's existing accessibility strategy is broadly divided into two phases:

(1) the planning and construction of accessible infrastructure

(2) the operation and management of passenger assistance services.

During the planning phase, TfL consults with disabled passengers, NGO groups, and London borough councils. Feedback from these groups informs the design and placement of new lifts, ramps, and other accessible features at stations. The planning process is guided by the Design Standards for Accessible Railway Stations issued by the Department for Transport. In cases where historical constraints make full compliance impossible, TfL must apply for an exemption from the Office of Rail and Road (ORR).

This stage also includes cost-benefit analysis and funding assurance. However, there is no fixed timetable to guarantee the implementation of step-free upgrades at specific stations. Progress depends heavily on funding availability and the pace of project approvals. For instance, the recent Future Step-Free Access Public Consultation (2021–2022) received over 5,500 public responses, helping TfL identify priority stations for future upgrades. Yet, despite this extensive input, the actual execution of these upgrades remains indefinite and significantly delayed.

Once step-free stations are constructed and accessibility infrastructure is in place, TfL is responsible for the' maintenance and service management of these facilities. According to the official policy documents, TfL commits to providing services that are "portable, safe, and reliable." Under this vision, TfL has introduced a "turn up and go" assistance model for disabled passengers. In this system, passengers are not required to book assistance in advance; instead, they may request help directly from staff upon arrival at the station. Staff members can assist with boarding, and in the case of wheelchair users, provide a manual ramp and ensure that assistance is available at the destination station.

To support this, staff use an internal app to coordinate assistance and log relevant passenger information, allowing for advance notification at the receiving station. However, it is essential to note that no guaranteed service waiting time is specified. The policy only states that "during busy periods, disabled passengers may experience short delays," which encourages passengers to arrive at least 10 minutes early.

Another critical aspect of operational management is the maintenance of accessibility equipment, particularly the manual boarding ramps used at many “step-free from street to platform” stations to bridge the platform–train gap. The policy states that staff should regularly inspect these ramps for safety and usability. Moreover, when lifts, escalators, or ramps are out of service, the policy states that staff should offer alternative arrangements, such as rerouting passengers to other step-free stations or providing free accessible taxis.

However, during this study’s simulated journeys, such responses were not observed in practice. For example, at Canary Wharf, where a lift was out of service, I used the Help Point to seek assistance. The staff advised me to reroute to another station, without offering information about taxi services or alternative arrangements, despite these options being noted in the policy.

Although TfL has established formal policies concerning the management and support of accessibility infrastructure, gaps remain between policy intentions and operational realities. These inconsistencies further justify the need to introduce temporal performance as a new evaluation dimension and to reconceptualise accessibility through the framework of time as infrastructure—a concept that will be explored in the next section.

5.2 Time as Infrastructure: A New Policy Framework

This research proposes a new policy framework that treats time as a fundamental infrastructure component to strengthen Transport for London's (TfL) accessibility strategy.

Within this framework, temporal performance—including factors such as passenger waiting times, the duration of infrastructure downtime, and the speed of repairs—is integrated into all planning, design, operation, and evaluation stages. By introducing the concept of "Time as Infrastructure", TfL can begin to prioritise the time experiences of disabled passengers and work to reduce the time barriers they face within the Underground system.

This proposed framework is structured around three key phases:

1. Planning and Construction,

2. Daily Operations and Infrastructure Management, and

3. Feedback, Evaluation, and Iterative Improvement.

The following sections detail policy recommendations for each of these phases.

Planning and Construction Phase

In the planning stage of step-free station projects, TfL should explicitly incorporate time into the planning process rather than make open-ended promises. When determining which stations require upgrades, this policy proposes using time-based indicators, such as:

- Prioritising stations with complex interchange structures or a high number of connecting lines for accessibility upgrades;

- For example, considering the following time-related metrics:

  - o How much additional travel time is required for wheelchair users at stations without lifts?

o How many disabled users would have their commute times significantly reduced after upgrades?

These indicators can help quantify the benefit of an accessibility project in terms of "time saved" and integrate this into cost-benefit analyses, making time an economic justification for implementation.

Time should be incorporated as a key design indicator in the infrastructure design phase. For instance, designers should aim to minimise the distance between step-free entrances, corridors, and platforms to shorten travel time, treating unnecessarily long detour routes as design flaws that need improvement. TfL's design department could adopt policy guidelines based on time benchmarks, such as:

"The travel time of an accessible route should not exceed that of the standard route by more than 25%."

The physical layout of station infrastructure and equipment should also reflect temporal concerns, so that infrastructure design considers not only accessibility but also speed of use and reliability. For example, wayfinding signage for disabled passengers should be placed at station entrances and include estimated travel times for accessible routes, helping passengers understand the station's complexity and journey duration from the outset. Additionally, real-time information screens should be placed at key decision points to notify passengers about the current status of accessibility infrastructure, helping reduce unexpected time barriers caused by outages.

Operations and Management Phase

Time-based targets should be included in staff performance expectations in daily operations. TfL could implement performance standards for accessibility services, such as setting maximum waiting times for assistance. For example, staff should respond to assistance requests within 5 minutes, and 90% of requests should be answered within this timeframe.

Regarding ramp deployment, TfL could digitally manage staffing schedules based on demand. The system would analyse passenger flow and infrastructure load to predict where and when assistance is most needed, and allocate more staff.

The policy framework proposes developing a real-time information system in cases of unexpected infrastructure failure. This would be integrated into the existing TfL Go app to include accessibility alerts, pushing automated warnings to subscribed passengers. Simultaneously, information at station exits would be updated, reducing the time barrier caused by unexpected inaccessibility.

Feedback and Evaluation Phase

In this phase, Time as Infrastructure would serve as a measure for evaluating the temporal continuity and performance of accessible routes. The system would collect data on:

- Average assistance response time;
- Duration of out-of-service periods for accessibility infrastructure;
- Survey data on how much extra travel time wheelchair users experience due to service interruptions.

These time-based indicators would be integrated alongside traditional metrics such as the number of assistance requests or complaints, positioning time as a core feedback metric for accessibility policy. In addition, the evaluation process would include surveys on disabled passengers' satisfaction with time performance, asking whether they experienced unnecessary delays and whether they perceived time barriers during their journeys.

Time as Infrastructure functions as a policy framework grounded in temporal performance, aiming to move beyond current systems that primarily evaluate accessibility through the presence or absence of physical infrastructure. The goal is to assess whether infrastructure exists and whether it is usable, efficient, and free of unnecessary time burdens. The ultimate aim is not only to improve disabled passengers' travel experience, but also to recognise time as a fundamental factor influencing urban mobility.

Chapter 6 Conclusion

This research explored the hidden dimensions of accessibility in the London Underground system, focusing on the Elizabeth Line and Jubilee Line as case studies. Through mapping, simulated journeys, and critical policy analysis, the study examined how wheelchair users experience barriers that are not always visible in current infrastructure evaluations. While the limited number of simulated journeys restricts the ability to make generalised claims, the findings still clearly demonstrate that the existing TfL framework, primarily focused on the existence and coverage of physical infrastructure, fails to account for the temporal realities faced by disabled passengers.

The study identified three main types of time barriers:

(1) Delay-based barriers, caused by long waiting times for lifts or assistance;

(2) Detour-based barriers, resulting from unclear signage or infrastructure layout requiring longer travel paths; and

(3) Blockage-based barriers, where service disruptions prevent progress entirely.

These barriers were consistently observed during the nine simulated journeys, suggesting that they are not anomalies but symptoms of broader systemic issues.

Through the development of a time-based infrastructure assessment method, applied to selected stations, the study showed that even stations labelled "step-free" often require wheelchair users to spend significantly more time navigating the space than predicted by TfL. This finding highlights a key disconnect between physical accessibility and practical usability.

In response, this thesis proposed a new policy framework: Time as Infrastructure, which positions temporal performance as a critical component in evaluating, designing, and managing accessibility. By integrating metrics such as assistance waiting time, travel delays, and infrastructure downtime into official planning processes, TfL could more accurately reflect the real-world experiences of disabled passengers.

Ultimately, the study argues that accessibility cannot be meaningfully achieved through physical upgrades alone. Without recognising time as a central aspect of mobility, accessibility policies risk overlooking the daily challenges disabled travellers face. Time as Infrastructure offers a way forward that moves beyond simplistic definitions of access and towards a more equitable, responsive, and inclusive urban transport system.

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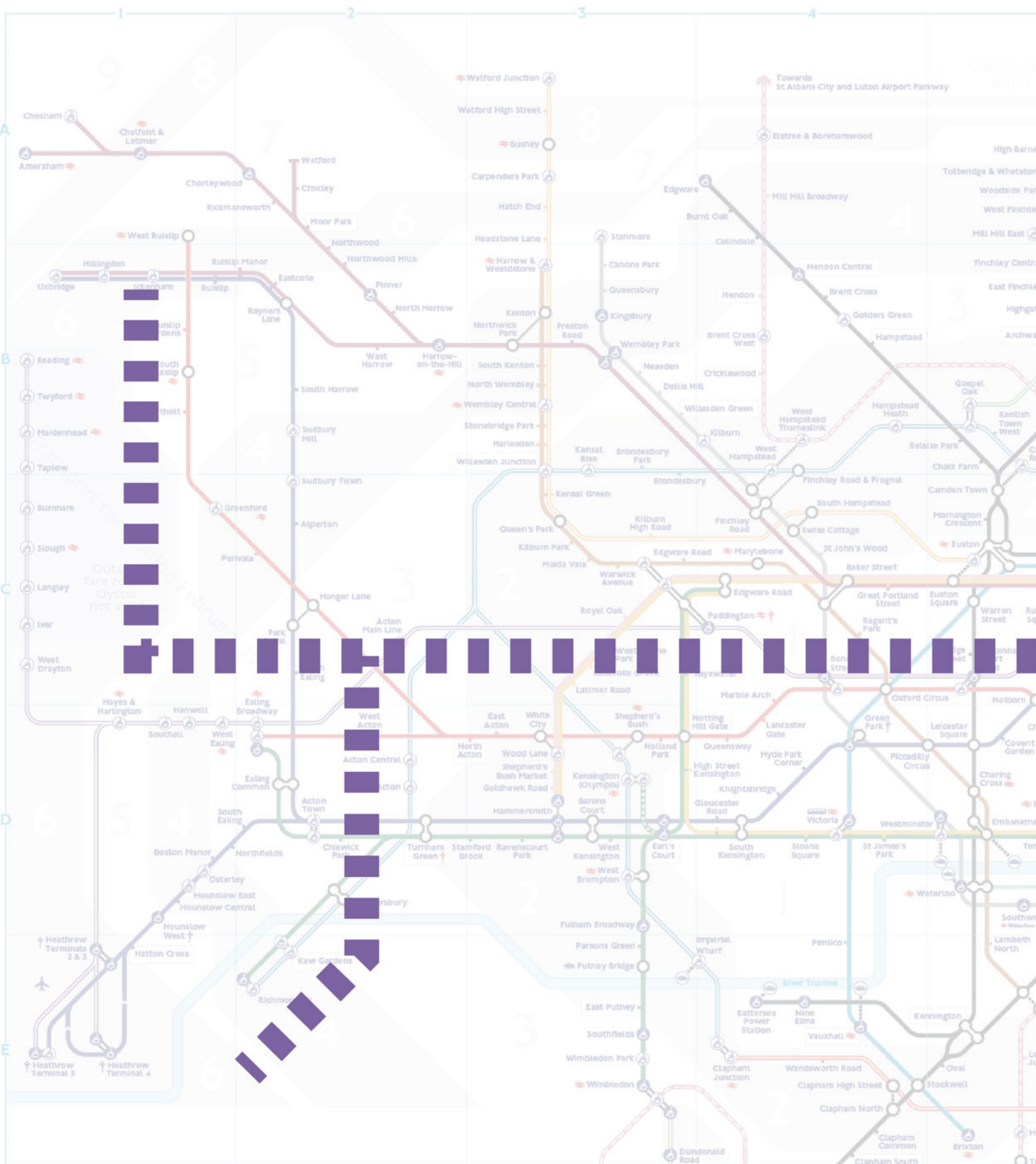

Key to symbols

- Interchange stations
- Internal interchange
- Under a 10 minute walk between stations
- Step-free access from street to train
- Step-free access from street to platform
- National Rail interchange
- Airport
- River services interchange
- Victoria Coach Station
- IFS Cloud Cable Car
- Outside fare zones, Oyster not valid
- Moor Park: Station in both fare zones

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