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The University of Osaka

Doctoral Dissertation

Study on Impact of the COVID-19 Pandemic on
Human Behavior Changes in Station Spaces of
Railways in West Japan

— Comparative Study before and after the
COVID-19 Pandemic—

西日本における鉄道駅空間での滞在行動特性の変容
に及ぼす COVID-19 の影響に関する研究
— コロナ前後の比較分析 —

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Abstract

The COVID-19 pandemic has significantly changed urban life worldwide, especially impacting public transportation spaces. In Japan, where railway stations are deeply embedded in daily mobility and urban structure, station plazas, concourses, and nearby commercial areas serve as key nodes for transit, commerce, and public interaction. This dissertation examines how the pandemic altered human behavior in these station environments, focusing on three case studies in western Japan: concourse shops in West Japan Railway Company stations, rest spaces within Osaka Monorail station concourses, and the JR Himeji Station Front Plaza North. A mixed-methods approach is used, combining long-term field observations, spatial analysis, demographic surveys, and big-data tools (KDDI Location Analyzer) to compare behavior before and after COVID-19; data from multiple periods are analyzed to understand the pandemic's influence over time.

Chapter 1 introduces the research background, reviews relevant literature on public space use and behavioral changes in transport settings, and clarifies the objectives, scope, and methodology of the study. It explains why Japanese railway stations and their related public spaces are socially significant and formulates the research questions regarding changes in stay behavior, facility use, and spatial preferences under the impact of the pandemic.

Chapter 2 (Case Study 1) analyzes concourse shops in 13 West Japan Railway stations by comparing passenger numbers and in-station retail usage between 2008 and 2021. It clarifies how shop usage declined more sharply than passenger numbers, how these declines varied by station location (downtown versus suburban) and shop position (in front of versus beside ticket gates), and how spatial visibility and functional importance affected commercial resilience.

Chapter 3 (Case Study 2) investigates behaviors at rest spaces in Osaka Monorail concourses, using survey data from 2008 and 2022 to examine changes in the number of stays, stay behaviors, and passenger flows. It shows that after the pandemic, dwell times in concourse rest spaces became shorter, temporary facility usage decreased, and the concourses shifted from places for lingering and small-scale social interaction to primarily pass-through circulation spaces.

Chapter 4 (Case Study 3) focuses on JR Himeji Station Front Plaza North, integrating field observations from 2017 and 2022 with continuous population data from 2018–2023 provided by KDDI Location Analyzer. It clarifies how the number of stays in the plaza, their spatial

distribution between the Lawn Area and Castle Garden, and the composition of user behaviors and age groups changed after COVID-19, and demonstrates a shift toward greener, more open, and psychologically “safer” areas.

Chapter 5 synthesizes the empirical findings from the three case studies, comparing outdoor plazas, indoor concourses, and in-station commerce. It identifies common post-pandemic behavioral patterns and interprets them through perspectives on public space and transit resilience, drawing out key implications for station design and management in the post-pandemic era.

Chapter 6 concludes the dissertation by summarizing how the pandemic changed the use, spatial distribution, and behavioral patterns in station spaces. It proposes recommendations for post-pandemic station planning and policy, acknowledges limitations in temporal coverage, geographic scope, and data sources, and outlines directions for future research, including long-term monitoring, perception surveys, and scenario-based simulations.

Across all three case studies, the findings reveal similar adaptations in how users occupy and move through station spaces: dwell times are shorter, crowded areas are avoided in favor of open-air or well-ventilated locations, and individuals maintain greater interpersonal distance. Station use has become more concentrated in essential travelers, while many non-essential groups (students, tourists, elderly) have been slower to return, resulting in a more commuter-focused user mix than before. By linking these observed behavioral changes to pandemic-related constraints, the dissertation provides practical insights for urban design and transportation planning under public health challenges and contributes to the broader discourse on resilient urban planning, demonstrating that adaptability, inclusivity, and spatial flexibility are essential for maintaining public space use and vitality in the post-pandemic era.

Keywords: COVID-19 Pandemic; Station Plazas and Station Concourses; Urban Public Space; Human Mobility Patterns; Behavioral Change; Location Data Analysis

List of Publications

Journal Papers

1. Mao, J., & Yokota, T. (2025). Study on Human Behaviors at the Rest Spaces in the Concourses of the Osaka Monorail: Comparative Study before and after the COVID-19 Pandemic. *AIJ Journal of Technology and Design*, 31(78), 911–916.

毛駿亜・横田隆司 (2025). 「大阪モノレールの改札内コンコースにおける休憩スペース等での人間行動特性：コロナ前後の変化に関する比較研究」『日本建築学会技術報告集』第 31 巻第 78 号, pp. 911–916.

2. Mao, J., & Yokota, T. (2025). Impact of COVID-19 Pandemic on Behavior Changes of People Staying in Station Front Plaza: A Case Study of JR Himeji Station Front Plaza North. *Journal of the City Planning Institute of Japan*, 60(3), 1650–1657.

毛駿亜・横田隆司 (2025). 「駅前広場における滞在者の行動変容に及ぼす COVID-19 の影響：JR 姫路駅北駅前広場を事例として」『都市計画論文集』第 60 巻第 3 号, pp. 1650–1657.

Conferences

Presentation: “Changes in Passenger Use of Concourse Shops after the COVID-19 Pandemic at Stations of the West Japan Railway Company” at the International Conference of Asia-Pacific Planning Societies, August 2023, Danang, Viet Nam.

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CHAPTER 1 INTRODUCTION

1.1 Background

The COVID-19 pandemic triggered unprecedented global disruptions in urban life, radically changing how people use public and transit spaces. Starting in early 2020, most countries imposed strict lockdowns, travel bans, and social-distancing rules. As Stevens et al. (2021) note, “the COVID-19 pandemic has had a dramatic impact on the way in which the community interacts within public spaces.” Streets, plazas, parks, shopping centers, and transit hubs around the world emptied almost overnight. Public transport ridership plummeted (Jenelius and Cebecauer, 2020), and many people shifted to working from home. In numerous cities, only outdoor open spaces were allowed to stay open, while indoor malls and recreational facilities closed. The need for distancing and infection prevention led to widespread behavioral changes: mask-wearing and hand hygiene became almost universal, similar to patterns observed after the 2003 SARS outbreak in East Asia. For instance, during SARS in Hong Kong, over 80% of the public adopted masks, and nearly everyone increased handwashing within days. These changes—initially temporary—have become ingrained habits during COVID-19.

Railway stations are especially vital in this context, particularly in Japan, where rail is the backbone of urban mobility. In Tokyo, for example, rail transit carried over half of all commuters (51% mode share in 2018), and nationwide, Japan’s private and public rail systems transported millions of people daily. Japan’s limited flat land and high population density led to rail-centered urban development: historically, private railway companies built extensive suburban lines and integrated major commercial facilities at the ends or along the lines to attract riders. In fact, Japan was a pioneer in transit-oriented development (TOD)-urban neighborhoods designed around railway hubs. As Cao et al. (2022) describe for Tokyo, Japan Railway (JR) lines “connect major urban nodes in both central and suburban Tokyo, and therefore became the skeleton of Tokyo’s transit systems.” Station plazas in Japan, such as Shibuya’s Hachiko plaza or Himeji Station’s lawn area, serve as public squares with shopping, dining, and waiting areas radiating from the train platforms. This unique social and spatial role makes stations not just transit points but also focal points for pedestrian activity and local commerce.

The pandemic’s social and spatial impacts on stations have been profound. Overall, passenger flows through stations dropped dramatically during emergency periods, and many

travelers avoided peak hours or shifted to private modes. Dai et al. (2024) find that “stations in large cities had higher ridership but were also more affected than smaller cities” by COVID-19. In other words, major urban terminals saw larger declines in foot traffic, whereas smaller regional stations retained more of their pre-pandemic vitality. Spatially, people reconfigured how they use station plazas and concourses: there was a strong preference for walking routes and waiting areas that allowed greater separation, while crowd-intensive areas (such as crowded ticket halls or central seating areas) became underutilized. Observers noted that “pre-COVID public spaces were surprisingly resilient with proportionally few elements completely unavailable.” Still, under COVID restrictions, the station system remained “significantly constrained in achieving and optimizing community and individual health and well-being”. In practice, this meant shorter dwell times in concourses, reduced window-shopping at station shops, and more limited gatherings at station square benches or fountains. Even amenities like rest areas and public pianos in plazas saw sharp declines in use, reflecting people’s heightened caution about shared surfaces and close contact.

Understanding these behavioral shifts is critical for urban resilience and planning. Urban planners and transport agencies must adapt designs to maintain functionality during future outbreaks. As Kermanshah (2020) argues, cities must now prioritize resilience against epidemics, noting that “urban planning and design play a prominent role in building resilience” to pandemics. For Japan’s dense cities, where stations intertwine with daily life, this means reconsidering how station areas can flex to new public health norms—for example, by widening pedestrian areas, adding touchless interfaces, or creating flexible stall layouts. Historical crises offer useful parallels: after the 2003 SARS epidemic, East Asian societies adopted enduring hygiene habits (widespread mask usage and hand sanitizers), and after major earthquakes (2011 Tohoku earthquake), transit systems learned to recover connectivity under strain. Tokyo’s rail network itself was resiliently expanded after the 1923 Great Kanto Earthquake, when rebuilding efforts integrated subway lines and elevated heavy rail (the Yamanote loop) to connect shaken urban districts. In each case, adaptive responses in infrastructure, from earthquake-proofing tracks to redesigning concourses, were vital. Similarly, the COVID-19 era underscores the need for planners to anticipate not only the recovery of ridership but also lasting behavioral changes.

Throughout history, large-scale health crises have forced cities to reshape how they use public space. The 1918 influenza epidemic, for instance, led many cities worldwide to regulate public gatherings (closing schools and theaters) and eventually improve outdoor sanitation. More recently, after the 2003 SARS crisis, many individuals in Japan and Hong

Kong had already been routinely carrying masks when ill or during flu season. COVID-19 effectively normalized these behaviors on a mass scale. As a result, understanding current shifts in station-area behavior is not merely academic: it informs how cities can remain resilient in the face of future pandemics. By studying West Japan Railway's station spaces, from the Himeji Station front plaza to urban concourses, we aim to capture how societal changes (social distancing, travel habits) manifest spatially. These insights can guide more flexible, inclusive station design and help policymakers craft adaptive public health strategies. In sum, the global impact of COVID-19 on human behavior in public places, combined with Japan's railway-centric urban form, makes this research timely for both local transit planning and the broader goals of creating pandemic-resilient cities.

1.2 Related Works

The COVID-19 pandemic has significantly affected public behavior and how urban spaces are used, especially in crowded areas like transportation centers. This chapter reviews the literature on how public space use changes, the pandemic's impact on spatial behavior, and the tools and methods used to analyze these shifts. Insights from previous studies lay the groundwork for understanding the behavioral changes examined in this research.

1) Public Space Utilization Pre- and Post-Pandemic

A growing body of research explores how the COVID-19 pandemic has changed the use of public spaces worldwide, comparing conditions before and after the outbreak. In many cities, outdoor public areas such as parks, plazas, and pedestrian streets became either a refuge or a site of adaptation. For example, Helmi et al. (2024) studied park usage in Nicosia and found that, although parks were among the few amenities remaining open, overall visitation decreased during lockdowns. Higher usage still occurred in good weather, but strict health measures and fear of infection caused many people to avoid even green spaces. Similar patterns are noted in surveys of U.S. and European cities: while parks provided psychological relief, visitation in 2020 was often much lower than pre-pandemic levels. Conversely, some localities experienced increases in park use once restrictions eased, as residents sought outdoor recreation. These varied findings show that spatial and seasonal factors influenced public space use.

Station plazas are a unique type of public space. Unlike parks, these areas are closely connected to transit flows and combine indoor and outdoor elements. In Japan and elsewhere, station fronts often served as informal outdoor communal spaces. Studies before COVID-19 showed heavy use of these plazas for brief gatherings or waiting. During the pandemic,

however, many station plazas experienced sharp declines in casual use. Data from mobile phones reveal that foot traffic in station areas dropped significantly during state-of-emergency periods. For example, Dai et al. (2025) analyzed 69 Japanese stations and identified five different patterns of demand change; overall, large city stations lost more activity proportionally than smaller stations. They observe that “stations in large cities had higher ridership but were also more affected than smaller cities” by COVID-19. In practice, this means that large, multi-use plazas shifted from busy meeting spots to nearly empty spaces during peak restrictions, while mid-sized station forecourts experienced milder declines.

Comparative examples from around the world illustrate these trends. In Asia, cities such as Seoul, Singapore, and Hong Kong experienced sharp declines in transit usage and pedestrian flows. Seoul’s subway system saw a 70–80% drop in ridership at the height of Seoul’s outbreak, leading to unusually quiet station concourses. Researchers in China have documented how major train stations were repurposed as field hospitals or triage centers, effectively temporarily closing public spaces. In contrast, some North American cities experimented with converting streets and station plazas to pedestrianized areas. New York City’s Open Streets program turned dozens of traffic corridors into car-free public spaces for socially-distanced walking and dining. Notably, a New York City DOT study found that restaurants on Open Streets saw far stronger sales growth than similar businesses on regular streets, indicating that expanded public space can support urban vibrancy even under pandemic conditions. European cities likewise adapted: for instance, Paris and London widened sidewalks and bike lanes in front of major stations to reduce crowding.

Comparing station plazas with other urban venues reveals some differences. Enclosed shopping malls—high-density retail spaces—were often fully closed during lockdowns, leading retail centers connected to stations to shut down. Many commuters avoided indoor malls due to poor ventilation and the need for masks. In contrast, parks and waterfronts tended to stay open and were sometimes more popular since people saw them as safer. In essence, station plazas in Japan strike a middle ground: they are semi-public, open-air spaces that remain legally open in most phases, but visitor numbers declined because of fewer trains. Data shows spatial differences: areas within a station plaza that had seating or vendors saw little traffic, while walkways still saw some use. Studies of West Japan Railway concourses, for example, found that convenience stores lost most of their customers after COVID-19, whereas ticketing areas—crucial for accessing trains—kept a basic flow.

In summary, pre-pandemic studies described station plazas as lively multiuse squares; post-pandemic work shows they are now largely underused except for essential transit functions.

Scholars highlight that public space use has been reshaped by health concerns: many people prefer uncrowded, open-air environments and avoid “social nodes” where distancing is difficult. The emerging literature from 2020–2024 clearly shows a shift in space utilization: outdoor plazas and parks remain key community resources, but their actual use patterns have changed, while traditional indoor public places see little activity. Understanding these global and regional examples offers context for Japan’s station spaces, where the pandemic has similarly changed how and where people gather.

2) Behavioral Changes in Transportation Spaces

Researchers have carefully studied how people’s behaviors in transit-related spaces—station concourses, platforms, and access points—have changed during the pandemic. A consistent finding is that social distancing and hygiene concerns have led to shorter stays, smaller groups, and more efficient movements. For example, an observational study of Himeji Station (Hyogo Prefecture) found that after COVID-19, users tended to avoid densely packed seating areas and instead used the edges of the plaza that provided more space. Yanagawa et al. (2022) report similar results: visitors at station plazas gravitated toward spots that allowed for meetings but still maintained spacing, avoiding the central cluster of the plaza. In Osaka, analysts observed a noticeable reduction in casual lingering at the Monorail network’s concourses; the average rest time on benches decreased by over 30%, reflecting increased caution. These changes mirror patterns seen in other cities: people entering stations more often head straight to exits or platforms, reducing wandering or loitering.

The demographic makeup of station users has also changed. Studies note a relative decline in non-essential travelers—such as students, tourists, or occasional shoppers—and a larger share of essential workers, commuters, and older individuals in the remaining foot traffic. Liu and Kaneda (2021) found that at West Japan Railway concourses, the steepest drop in passenger numbers occurred outside traditional rush hours, suggesting a greater proportion of commuter travel compared to leisure travel after the pandemic. Likewise, global transit surveys indicated that higher-income and white-collar riders were more likely to skip transit, while transit-dependent populations continued to use it in larger numbers. This has spatial implications: station areas near business districts emptied out more than those near residential neighborhoods. For example, Hiroshima’s station plaza saw fewer afternoon shoppers but maintained a steady flow of local errands.

Researchers in other countries observe similar changes in behavior. In Seoul, smartphone data showed that after the epidemic declined, many people used the city’s numerous plazas and courtyards for short outdoor visits but avoided underground passages and mezzanines. In

London, a survey of Tube stations revealed that passengers swiftly spread out along platforms and rarely stood in traditional areas once mask mandates were in effect. Studies in New York found that crowd densities at Manhattan's Grand Central and Penn Station decreased by over 80% compared to 2019, with those who did enter choosing less crowded train cars and entrances. Across these examples, a common theme is increased health awareness: passengers kept more distance, touched surfaces less often, and even changed their body language.

Quantitative analyses confirm these findings. Yokota et al. (2011) studied Osaka Monorail concourse use through video tracking before and after the pandemic; they reported significant decreases in "temporary facility usage" and shorter stop durations at seating areas. In West Japan Railway concourses, detailed surveys have shown that shop patronage declined most during the morning rush and evening hours, when people hurriedly passed through without stopping. Yanagawa et al. also observed that group sizes in station spaces decreased: families or friends who previously gathered now tend to split up into singles or couples.

Overall, the literature shows a shift in how people prefer to use space in station environments. Covered waiting areas and public restrooms saw much lower foot traffic, while large open plazas continued to see cautious use. This led to a new pattern of behavior in transit spaces: people move purposefully with little delay, sticking to only essential routes. Scholars emphasize that these changes are not just temporary; they reflect a deeper shift in how users perceive safety in transit areas, which has implications for station design and operations. As one review notes, "different age groups and genders show varying preferences in how they use public spaces," so understanding these preferences is crucial for adaptable design.

3) Tools and Methods for Analyzing Public Behavior

To understand the dynamics of public behavior in stations and urban areas, researchers have used various advanced analytical tools. Mobility tracking data has been particularly valuable. For example, the DOCOMO Mobile Spatial Statistics (MSS) dataset-anonymized location data from millions of smartphones-provides hourly population counts within a 500m grid. This data enables the mapping of inflow and outflow patterns in and around stations over time. In one study, K-means clustering of MSS data identified distinct "diurnal mobility patterns" and showed how they changed during 2020–21. These large-data approaches have been validated in many COVID-19 studies: detailed phone data can reveal, for example, that foot traffic near a station dropped 70% immediately after an emergency was declared, then gradually increased as restrictions were relaxed. Google and Apple mobility reports have also

been used—though on a coarser scale—to monitor shifts in public transportation use and walking.

Beyond mobility data, spatial analytics tools like GIS-based heatmaps, flow maps, and statistical models have been used. Heatmaps created from geotagged data can show which parts of a plaza were most visited before and after the pandemic. Video analytics have also been tested to count people and measure distances between them in stations. For example, researchers might calibrate camera feeds to count how many people queue at a ticket gate or sit in a waiting area at different times. These observations can be linked to demographic surveys to understand “who” is using a given space.

In summary, modern research depends on a multi-method approach. Quantitative data are combined with spatial analysis and computational modeling. These tools provide detailed, empirical insights into behavioral changes. They also deliver actionable outputs—for example, heatmaps highlighting underused spaces can inform redesign, and predictive models can guide investment in station infrastructure. This array of methods has expanded rapidly since 2020, reflecting both the urgency of the pandemic and advances in AI-driven observation. The current study uses many of these techniques to expand this evolving toolbox of public-space analysis.

4) Long-Term Implications for Urban Design and Policy

The literature emphasizes that COVID-19 is transforming long-term urban planning priorities, particularly around resilience and inclusivity. In transportation hubs and plazas, the consensus is that flexibility and human-centered design are essential. For example, Stevens et al. (2021) suggest “design interventions”—such as modular seating, reoriented pedestrian flows, and the use of touchless technology—to help public spaces stay safe and welcoming during health crises. These ideas aim not only to restore community access during pandemics but also to enhance “inclusive access to a broader range of the community under all conditions.” In practice, this could involve designing station plazas with movable planters that can be reconfigured for social distancing or providing clearer signage for safe navigation. It might also mean making hygiene facilities permanent features.

From a policy perspective, academics advocate for incorporating resilience theory into urban planning. Holling’s concept of resilience—a system’s capacity to absorb shocks and adapt—has been applied to city transportation systems. Jenelius (2022) notes that resilience in public transit is “not only about returning to the pre-event state but also about adapting to new conditions.” This means, for example, that transit agencies should not just aim to restore 2019 ridership levels but also prepare for the possibility that some commuters will continue

teleworking or choose off-peak travel. In this view, a resilient station area might include mixed land uses and amenities that remain valuable even if commuter traffic declines—such as adding co-working spaces or health clinics within station complexes. Dai et al. (2025) emphasize this point by showing that mixed-use station areas proved to be the most resilient during COVID-19. Therefore, long-term planning may favor transit-oriented development schemes that keep stations lively even during times of stress.

Inclusive design is another major theme. COVID-19 has highlighted inequalities: marginalized populations often depending heavily on public transit and crowded station facilities. Planners are encouraged to address the needs of vulnerable groups—the elderly, disabled, or lower-income workers—in post-pandemic planning. For example, wider platform edges, clear wayfinding, and larger waiting areas benefit those who move more slowly or wish to avoid congestion. Afrin et al. (2021) call for pandemic-resilient planning that directly tackles social inequalities, noting that future urban strategies should combine physical infrastructure improvements with socio-economic measures. They recommend applying a Disaster Risk Management (DRM) framework across response, mitigation, and preparedness phases: short-term actions, medium-term technology adoption. Accordingly, many cities are re-examining building codes and public health guidelines for transport hubs to enhance safety for future epidemics.

Finally, the pandemic has spurred broader changes such as the 15-minute city and active transport movements, which influence station-area planning. If commuting decreases, planners are considering how to repurpose large central districts—including station plazas—for local living rather than just transit routes. The literature indicates that improving green space access and walkability around stations can strengthen community resilience against future shocks. For example, adding pocket parks or open markets in station areas can offer daily amenities and adaptable space for emergencies. These concepts are now being discussed by planning groups worldwide as part of post-COVID design strategies.

1.3 Objectives and Contributions

The primary objective of this research is to examine and understand behavioral changes and spatial dynamics in urban public and transportation areas caused by the COVID-19 pandemic. Focusing on railway station plazas, concourses, and shops in concourses, this study aims to identify the main impacts of the pandemic on passenger behavior, facility use, and spatial preferences. By analyzing case studies from Himeji Station Front Plaza, Osaka

Monorail concourses, and West Japan Railway concourse shops, the research intends to achieve the following specific objectives:

1) Analyze behavioral changes in public spaces

Examine how the COVID-19 pandemic has changed patterns of stay behavior, activity types, and spatial preferences in urban public spaces such as station plazas and concourses.

Compare pre- and post-pandemic data to identify significant shifts in demographics, group sizes, and activity durations.

2) Examine the impact on facility usage

Assess how the use of station facilities, including rest areas and concourse shops, changed during and after the pandemic.

Analyze how shop usage varies by time of day, passenger categories, and shop locations.

Explore how the design and placement of facilities like rest areas, shops, and vending machines affected passenger behavior during and after the pandemic. This involves analyzing the connection between facility layout, passenger movement, and temporary usage patterns in concourse areas.

3) Evaluate Spatial Distribution and Adaptations

Analyze how activities are distributed in plazas and concourses, using tools like heatmaps, to identify behavioral changes across various areas.

Analyze how spatial features and design elements affect passenger preferences and behaviors during a pandemic.

4) Evaluate the Pandemic's Impact on Mobility and Commercial Activity:

Analyze the decline in passenger numbers and how it relates to changes in shop use and spatial behavior. Examine the timing of these changes, especially shifts during morning, noon, and evening, as well as differences in boarding and alighting patterns.

5) Correlate Passenger and Facility Dynamics

Analyze the relationship between shifts in passenger numbers and facility usage, especially in shop patronage and short-term stays, to understand the indirect impacts of the pandemic on commercial and spatial dynamics.

6) Provide Insights for Post-Pandemic Urban Design and Policy:

Identify the implications of observed behavioral changes for urban design, transportation management, and commercial strategies. Provide recommendations for developing resilient and adaptable public spaces that meet evolving user needs in post-pandemic scenarios.

7) Develop Recommendations for Resilient Urban Design

Offer actionable insights for urban planners, transportation managers, and policymakers to design adaptive public spaces that respond to behavioral changes and bolster resilience in post-pandemic situations.

Provide specific design and management strategies for station plazas, concourses, and shops that address diverse public needs while prioritizing safety and functionality.

1.4 Structure of Dissertation

This dissertation is divided into six chapters. The main goal is to explain how the COVID-19 pandemic changed human behavior in public spaces at railway stations and to develop design and planning recommendations for post-pandemic urban transportation settings. Each chapter serves a specific purpose in supporting this argument (Figure 1-1).

Chapter 1 (Introduction) outlines the research background and motivation. It explains why railway stations and their related public spaces (station-front plazas, concourses, and station commercial areas) are socially significant in Japan, and how the COVID-19 pandemic created a new need to understand changes in how these spaces are used. This chapter also identifies the research questions, describes the study area and scope, details the data sources and analytical methods, and presents the overall research framework.

Chapter 2 (Case Study 1: Concourse Shops in West Japan Railway Stations) focuses on commercial activity inside railway stations. Using surveys from multiple stations, it compares retail usage inside stations before and after the pandemic. This chapter examines changes in customer numbers, differences in time of day (rush hour versus midday), and the spatial dependence of commercial recovery (shops near ticket gates and main flow paths versus shops in peripheral corridors). Chapter 4 shows that optional, leisure-oriented spending in concourses decreased sharply and that survival and recovery depended heavily on spatial visibility and the importance of services.

Chapter 3 (Case Study 2: Osaka Monorail Concourse Spaces) examines semi-enclosed circulation areas within station concourses. It compares behaviors before and after the pandemic in concourse “rest spaces,” such as seating areas and small waiting corners. This chapter investigates who stayed in these rest areas, how long they remained, changes in passenger flow patterns, and how temporary facility usage decreased after the pandemic. Chapter 3 explains how the concourse transitioned from a social or lingering environment to mainly a pass-through space.

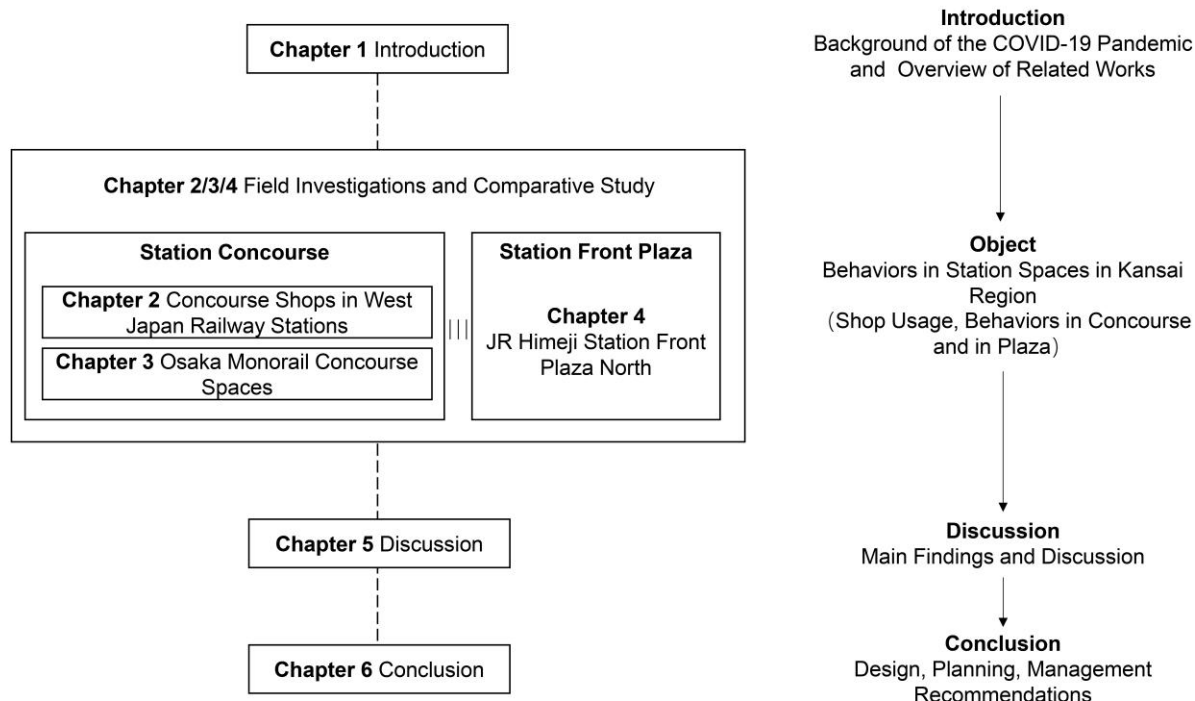


Figure 1-1 The flow chart of the dissertation and its relationship of each chapter

Chapter 4 (Case Study 3: JR Himeji Station Front Plaza North) looks at an outdoor, semi-public urban space directly connected to a major station. Using field observations from 2017 (before the pandemic) and 2022 (after the pandemic), along with continuous population data from 2018–2023, this chapter analyzes changes in (i) the number of people staying in the plaza, (ii) their spatial distribution within sub-areas such as the Lawn Area and Castle Garden, and (iii) their observed activities and demographic characteristics. Chapter 4 demonstrates how the pandemic caused not only a decline in overall usage but also a shift of stays toward greener, more open areas seen as safer and more comfortable.

Chapter 5 (Discussion) synthesizes the empirical findings from Chapters 2–4. It highlights common behavioral patterns across outdoor plazas, indoor concourses, and station retail environments, such as shorter dwell times, avoidance of crowded central areas, redistribution toward perceived “safer” spaces, and the narrowing of user groups to primarily essential travelers. It then interprets these patterns in relation to existing literature on public space, transit resilience, and pandemic-responsive urban design. Finally, Chapter 5 explores implications for future station design and management, including modular seating, distributed micro-waiting zones, touchless circulation, improved ventilation, and spatial strategies that support psychological comfort and physical safety.

Chapter 6 (Conclusion) summarizes the main contributions of the study. It restates how the pandemic changed not only how many people used station spaces but also where they stayed, how they behaved, and which activities they continued to perform. It then offers recommendations for post-pandemic station planning and policy, covering issues such as flexible spatial layouts, health-focused infrastructure, and multimodal access. Chapter 6 also recognizes the study's limitations (temporal coverage, geographic focus, and reliance on observational data) and suggests directions for future research, including long-term monitoring, user perception studies, and scenario testing based on simulations.

In summary, Chapters 2–4 present empirical evidence from three complementary spatial typologies (outdoor plaza, indoor concourse, and in-station commerce), while Chapters 5 and 6 apply these findings to theory, policy guidance, and future research directions.

1.5 Methodology

1.5.1 Research Objectives

The primary goal of this research is to explore and understand how the COVID-19 pandemic has changed behavior and spatial use in urban public and transportation areas. Focusing on railway station plazas, concourses, and shops within concourses, this study aims to identify the main effects of the pandemic on passenger behavior, facility usage, and spatial preferences. By analyzing case studies from Himeji Station Front Plaza, Osaka Monorail concourses, and West Japan Railway concourse shops, the research seeks to accomplish the following specific goals.

1) Analyze Behavioral Changes in Public Spaces

Examine how the COVID-19 pandemic has changed patterns of stay behavior, activity types, and spatial preferences in urban public spaces such as station plazas and concourses.

Compare pre- and post-pandemic data to identify significant changes in demographics, group sizes, and activity durations.

2) Analyze the Impact on Facility Utilization

Evaluate changes in the use of station facilities, including rest areas and concourse shops, during and after the pandemic.

Analyze differences in shop usage based on time of day, passenger types, and shop locations.

Examine how the design and placement of facilities (such as rest areas, shops, and vending machines) affected passenger behavior during and after the pandemic. This involves

analyzing the connection between facility layout, passenger movement, and temporary usage patterns in concourse spaces.

3) Evaluate Spatial Distribution and Adaptations

Study the spatial distribution of activities in plazas and concourses, using tools such as heatmaps to reveal behavioral changes across various areas.

Analyze how spatial features and design elements affect passenger preferences and behaviors during pandemic conditions.

4) Evaluate the Pandemic's Impact on Mobility and Commercial Activity:

Examine the decline in passenger numbers and how it relates to changes in shop usage and spatial behavior. Investigate the timing of these changes, especially shifts in behavior during morning, midday, and evening hours, as well as differences in boarding and alighting patterns.

5) Correlate Passenger and Facility Dynamics

Analyze the relationship between changes in passenger numbers and facility usage, especially in shop patronage and temporary stays, to understand the indirect effects of the pandemic on commercial and spatial dynamics.

6) Provide Insights for Post-Pandemic Urban Design and Policy:

Identify the implications of observed behavioral changes for urban design, transportation management, and commercial strategies. Provide recommendations for developing resilient and adaptable public spaces that meet evolving user needs in post-pandemic scenarios.

7) Develop Recommendations for Resilient Urban Design

Offer practical insights for urban planners, transportation managers, and policymakers to develop adaptable public spaces that respond to behavioral shifts and boost resilience in post-pandemic settings.

Recommend specific design and management strategies for station plazas, concourses, and shops that accommodate diverse public needs while maintaining safety and functionality.

1.5.2 Scope and Methodology

This research examines the effects of the COVID-19 pandemic on public behavior and spatial patterns in urban transportation areas in Japan. It focuses on three distinct case studies: the West Japan Railway concourse shops, Osaka Monorail concourses, and JR Himeji Station Front Plaza. The study examines key themes such as changes in how people stay, use facilities, and distribute themselves spatially. It highlights shifts in passenger interactions and preferences in public spaces before and after the pandemic. The scope includes various urban

settings: the Lawn Area and Castle Garden at Himeji Station Plaza, rest spaces across 14 Osaka Monorail stations, and concourse shops at 13 stations along the West Japan Railway lines. These sites cover outdoor, semi-outdoor, and indoor environments, making them ideal for analyzing behavioral changes caused by the pandemic. Using a comparative approach, the study identifies how these spaces transformed before and after COVID-19 to offer useful insights for urban design and facility management.

A multi-method approach was used to understand the dynamics of these spaces. Field surveys and observational studies took place during similar periods before and after the pandemic (2008, 2017, 2021, and 2022), collecting detailed data on passenger behaviors, including stay locations, durations, activity types, and demographic information. Real-time analytics, such as heatmaps and demographic trends, were generated using tools like the KDDI Location Analyzer. Comparative analyses examined year-over-year differences, including weekday versus weekend patterns and changes throughout different times of the day. Statistical methods like paired-sample t-tests and regression models offered quantitative insights into the relationships between passenger counts and facility usage, highlighting important behavioral trends and spatial preferences.

The research also used classification frameworks to categorize spaces and facilities based on their functionality and design, highlighting how spatial characteristics influence user behavior. By integrating these methods, the study provides a thorough understanding of how the pandemic has changed public behavior and the use of transportation spaces, offering valuable insights for adaptive urban design and planning in a post-pandemic era.

1.5.3 Materials and Methods

1) Study Areas

This research examines three major transportation spaces in Japan, each highlighting distinct aspects of urban public and transportation facilities.

i) Himeji Station Front Plaza and Tenri Station Front Plaza

The study area includes the Lawn Area and Castle Garden at the JR Himeji Station Front Plaza North. These spaces are popular among both passengers and local residents, offering various activities like resting, socializing, and casual leisure. The Lawn Area is an open outdoor space with seating and direct links to roads and buildings, while the Castle Garden is an underground outdoor area connected to the station's commercial facilities.

ii) Osaka Monorail Station Concourses

Fourteen stations along the Osaka Monorail's main line were examined, focusing on concourse rest spaces and art spaces. These areas include facilities like vending machines, libraries, and rest corners. The concourses are semi-indoor transit spaces with diverse functions, such as temporary resting spots and short-term recreational uses.

iii) West Japan Railway Station Concourses

Thirteen stations of the West Japan Railway Company in the Kansai region, which include concourse shops like convenience stores, restaurants, and bookstores, were examined. These stations are located in various areas, including downtown and suburbs, and their concourses serve as indoor public spaces for transit and commercial activities.

2) Data Collection

Data for this study were collected through a combination of field observations, surveys, and advanced analytical tools at three case study sites—Himeji Station Front Plaza, Osaka Monorail concourses, and West Japan Railway concourse shops. Observational data at Himeji Station were gathered in 2017 and 2022, focusing on passenger behaviors such as stay durations, activity types, group sizes, and demographic characteristics within the Lawn Area and Castle Garden. Similarly, surveys at Osaka Monorail stations were conducted in 2008 and 2022, recording passenger flows, resting behaviors, and temporary facility usage in rest spaces and art areas across 14 stations. At West Japan Railway concourses, shop usage data from 2008 and 2021 were collected, emphasizing passenger demographics, shop visitation rates, and boarding and alighting patterns. The KDDI Location Analyzer provided critical data at Himeji Station, enabling real-time tracking of daily stays, visitor origins, and spatial distribution from 2018 to 2022. This tool was instrumental in generating heatmaps to visualize behavioral trends and spatial preferences. Additionally, video recordings at Osaka Monorail stations were used to analyze passenger flows, while standardized surveys aligned with previous studies ensured consistency across temporal and spatial variables. Observations were conducted during similar timeframes across years to account for seasonal and daily variations, allowing for robust comparisons of passenger behavior and facility usage before and after the COVID-19 pandemic.

3) Comparative Framework

A comparative framework was established to systematically analyze behavioral changes and spatial usage patterns across the pre-pandemic (2008, 2017) and post-pandemic (2021, 2022) periods. Temporal comparisons identified shifts in key metrics such as stay durations, activity types, and facility usage, while spatial analyses examined patterns in specific areas, including the Lawn Area and Castle Garden at Himeji Station and resting spaces at Osaka

Monorail stations. Heatmaps and spatial distribution tools visualized changes in usage density and spatial preferences, providing insights into how design elements influenced user behavior. For the West Japan Railway concourses, variations in shop usage were analyzed based on location types, including downtown versus suburban stations and shop placements near ticket gates.

Demographic factors such as age, gender, and group size were examined to identify behavioral trends, while weekday versus weekend usage patterns provided additional insights into temporal variations. Statistical methods, including paired-sample t-tests and regression analyses, were used to evaluate correlations between passenger numbers, facility usage, and behavioral changes, focusing on temporal and demographic variables. These analyses highlighted the impact of external factors like the pandemic on user preferences and spatial interactions, emphasizing the relationship between public behavior and the design of transportation spaces. By integrating temporal, spatial, and behavioral aspects, the framework provides a comprehensive understanding of how the pandemic reshaped public space usage, contributing to the broader discussion on urban resilience and adaptive design.

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CHAPTER 2 STUDY ON CONCOURSE SHOP UTILIZATION IN WEST JAPAN RAILWAY STATIONS

2.1 Introduction

2.1.1 Social Background

The COVID-19 pandemic started in 2020; as of now, it is 2023. Due to the disease's high infectivity and severity, most countries have implemented various measures and policies to prevent infections in crowded areas. According to the World Health Organization (WHO), people are advised to stay at least 1 meter apart from others (WHO, 2023). In Japan, individuals are required to wear masks, keep at least a 2-meter distance from others in public, and avoid the three Cs (MHLW, 2023).

Consequently, the COVID-19 pandemic has notably impacted daily life. Many researchers in Japan have studied changes in people's daily travel routines, the use of public facilities for reasons such as commerce, behavioral habits, and social distancing in public spaces. The density of the population in Tokyo and its three neighboring prefectures decreased under the influence of COVID-19 (Goto, 2022). There has been an increase in people moving to the suburbs and temporarily residing in suburban residential areas (Guo et al., 2022; Shiozaki et al., 2023). At the same time, short-distance travel grew while long-distance commuting via public transit declined during the COVID-19 pandemic (Ooshima, 2021). Studies comparing pedestrian walking behavior before and during the pandemic, using video recordings from 2015 and 2020, showed no difference in walking speed between the two years. However, pedestrians maintained a significantly longer avoidance distance in 2020 (Liu and Kaneda, 2021). It was also observed that the number of cafés, fast-food restaurants, and shopping malls decreased during the pandemic (Yanagawa et al., 2022).

Since the beginning of 2022, policymakers in Japan have eased restrictions on public gatherings due to the pandemic to balance the economy and people's health. Commercial and business activities have rebounded, and the operating hours of shops have expanded for many facilities. However, Japan has not fully recovered to pre-pandemic levels. Changes in people's behavior and their awareness in public spaces remain influenced by COVID-19, and these effects seem to have persisted for a long time (Yanagawa et al., 2022). The most notable

behavioral change is that people still wear masks indoors and perform hand disinfection before certain activities. A decline in public transit use and face-to-face interactions, along with an increase in working from home (WFH) and online activities, have been frequently observed (Wang, 2022). This suggests that people continue to be conscious of maintaining social distancing and avoiding infection since the end of the pandemic.

High-density facilities have been concentrated and developed at railway stations in Japan. People go about their daily lives and conduct business in station areas. During COVID-19, almost all railway lines experienced a decline in ridership, and shops and restaurants in and around stations shut down (Yahoo, 2020; HIROTA, 2020), demonstrating the direct impact of COVID-19 on railway stations. The indirect effects are changes in passenger behavior, such as passenger distribution, route selection, social distance, facility use, and time spent at stations (Fang, 2023).

Unlike the areas outside the station entrance, where people have free access, the concourse is an area that only ticketed passengers can enter. Several small shops are set up there as functional parts of the station. The concourse is also an inner space where many passengers gather within a short time period, and the facilities there heavily depend on the passenger numbers.

Therefore, a railway station concourse in Japan is a common and appropriate indoor public space for analyzing changes in people's behavior under the influence of the COVID-19.

2.1.2 Related works

Railway stations worldwide incorporate commercial spaces, but the pandemic has significantly changed their dynamics. Transit-oriented retail usually depends on commuter foot traffic and quick transactions: as one industry expert mentions, transit users “arrive at a station just minutes before trains” and prefer “grab-and-go” options. When COVID-19 caused ridership to drop, station retailers were severely impacted: many shops closed and sought rent relief. The MTR Corporation reported a decline in station retail income due to “boundary station closures” and concessionary rents, even as it prepares for eventual traffic recovery. This reflects global trends: foot traffic in transit-adjacent retail districts dropped sharply, pushing a shift toward online channels and delivery.

At a behavioral level, consumer shopping patterns shifted during COVID. E-commerce grew, and people limited in-person shopping. A recent study of shopping malls found that “while personal preferences were at the forefront before the pandemic, the characteristics of the place gained importance after the pandemic.” By analogy, commuters now evaluate

station shops based on health safety and convenience: well-spaced aisles, contactless payments, and outdoor or ventilated waiting areas matter more than ever. In planning, this supports calls for spatial marketing and mixed-use strategies. For example, experts suggest adding non-transit functions to station complexes to attract off-peak visitors and stabilize revenue (Jenelius, 2022; Dai et al., 2025). Jenelius (2022) argues that station area resilience depends on mixing land uses so that an area remains “valuable even if commuter traffic is lower.”

Finally, studies on station retail resilience highlight adaptability. In Japan and other regions, convenience stores at stations proved most resilient, as passengers continued to buy essentials. Globally, retailers note that flexible leasing and the integration of digital services are crucial for surviving sharp demand shocks. London’s Underground, for example, is experimenting with pop-up markets and revised concession terms to handle fewer office commuters. In summary, the literature suggests that station commerce during pandemics depends on: (1) commuter volume, tenant mix, space layout, marketing, and policy support. These themes set the stage for our West Japan Railway concourse shop analysis.

2.2 Investigations in 13 West Japan Railway stations

By focusing on passenger usage of concourse shops along railway lines in West Japan, we aimed to elucidate the characteristics of passenger behavior regarding shop use and to assess the impact of COVID-19 on changes in shop usage at station concourses. Through this study, we expect to better understand how people’s behavior in the inner spaces of public transit facilities has shifted under the influence of COVID-19.

We selected lines operated by the West Japan Railway Company in the Kansai region as the objects for this study for three reasons. First, the Kansai area is one of Japan's largest and most significant city regions, both in size and economy; it has the second-longest railway line and the second-highest passenger numbers. Additionally, the lines of the West Japan Railway Company rank second in turnover and third in annual passenger numbers, according to the 2022 census (GOO, 2022). Second, there are many stations with functional complexes along these lines, which allowed us to gather representative data. Third, this study builds on our earlier research (conducted in 2008 and 2010) on functional complexes and shop usage at station concourses belonging to the West Japan Railway Company (Yokota et al., 2011). It is a significant accomplishment to conduct further comparative research on the changes before and after COVID-19.

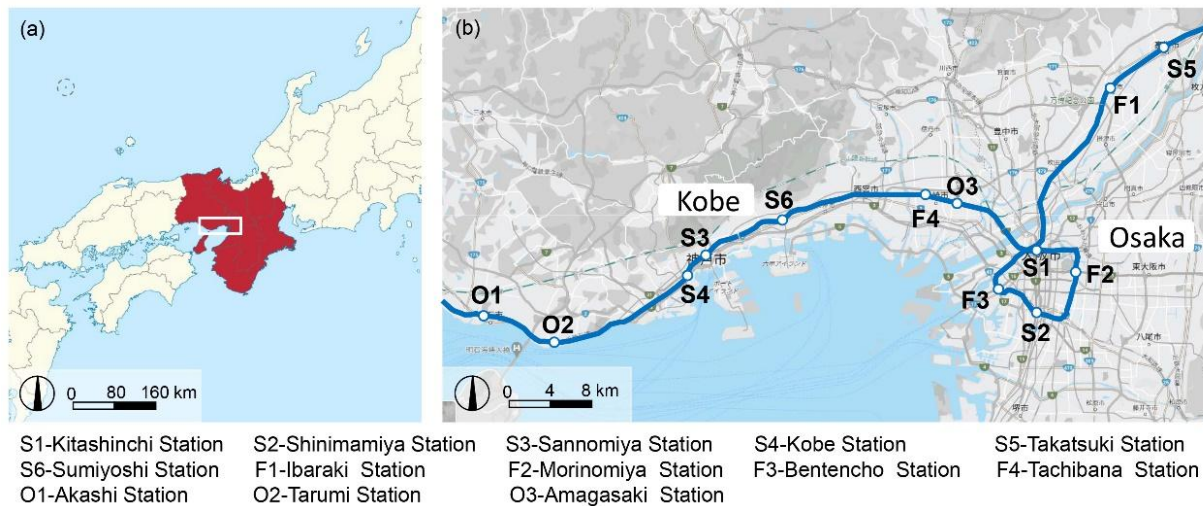


Figure 2-1 The location of 13 stations: (a) the Kansai region and study area; (b) the railway lines of the West Japan Railway Company and the locations of the 13 stations

We examined the changes in railway station concourses based on passenger numbers, facility usage, and passenger classification. Our previous study focused on passenger behavior in concourses at 13 stations operated by West Japan Railway Company. Building on this, we further examined passenger flow and facility usage in 2022 after the COVID-19 pandemic, completing a comparative study.

We selected 13 stations operated by the West Japan Railway Company based on our previous research (Figure 2-1). They are typical stations along the main railway lines in different locations, and all have functional facilities within their station concourses. Additionally, they offer different types of shops in their concourses: six stations have convenience stores, four have food stores, and three include multiple stores, such as restaurants and bookstores. This allowed us to compare shop usage and user behavior across various store types and station environments.

We studied each station on different days between November and December 2022. We scheduled observations for each station based on an investigation conducted in 2008 to ensure consistent conditions for comparison. Data was collected on users' information at a specific concourse during one-hour periods across three time slots: the morning from 7:45 a.m. to 9:00 a.m., the afternoon from 1:30 p.m. to 2:45 p.m., and the evening from 4:45 p.m. to 6:00 p.m. We recorded sex, age, boarding, and alighting, and we counted the number of users at each station. By comparing these results with those from before COVID-19, we identified changes in concourse layouts, especially in concourse shops.

2.3 Comparative study on Passenger and Shop Usage Changes

1) Changes in the passenger numbers

According to statistics on average daily passenger numbers at 13 stations from 2008 to 2021 (Figure 2-2), the figure remained stable until the COVID-19 outbreak in 2020, then decreased dramatically. Compared with 2008 (Figure 2-3), the average daily passenger numbers in 2021 declined by 15.51% at the 13 stations and by 21.51% at 12 of those stations (O3 excluded). The maximum decrease was 21.87% at S4, and the minimum increase was 5.04% at O3.

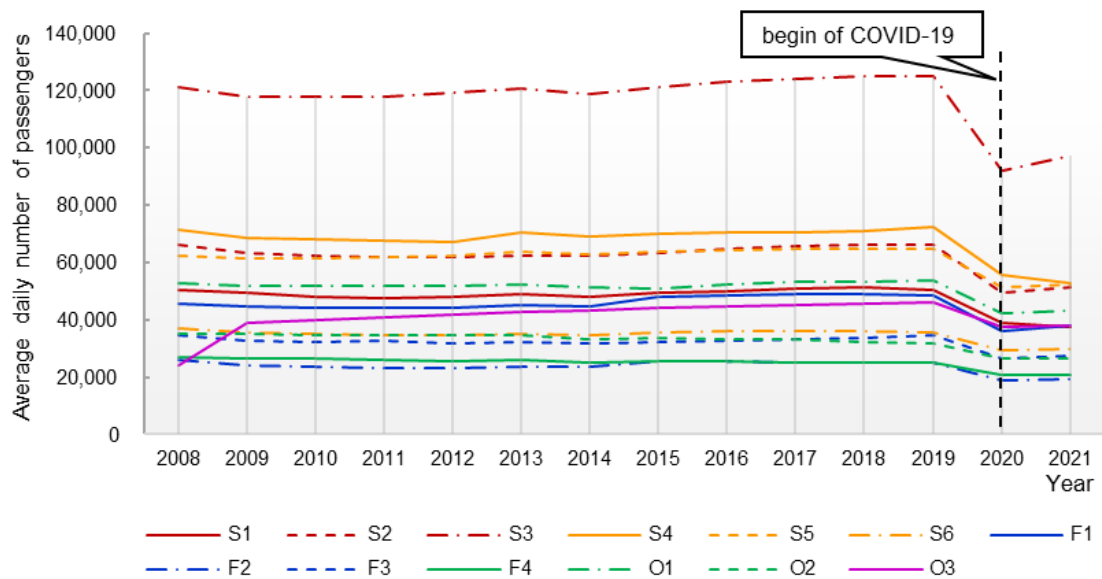


Figure 2-2 Changes in average daily passenger numbers in 13 stations from 2008 to 2021

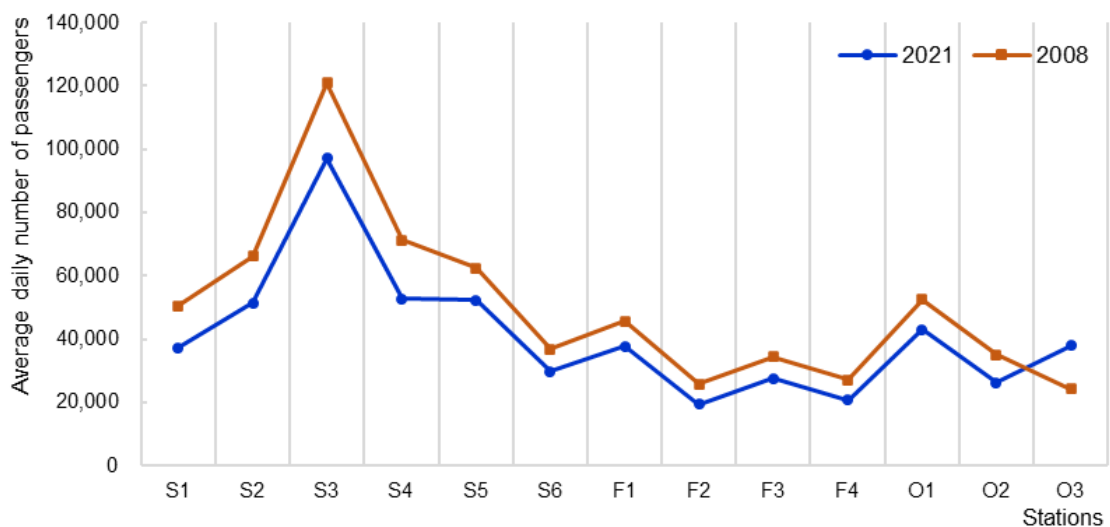


Figure 2-3 Comparison of average daily passenger numbers between 2008 and 2021

2) Changes on facilities in the concourse

Before conducting the comparative study on shop usage in concourses, we needed to clarify whether the concourse itself and its facilities had changed. Therefore, we investigated 13 stations and compared the results with our previous research from 2008. According to the outcomes shown in Table 2-1 and Figure 2-4, we noted several changes at six stations: S3, F1, F2, F3, F4, and O3. The shops in the concourse were closed at S3, F1, F3, and F4. Shops were relocated outside the concourse at F2. The bookstore at O3 was replaced by a convenience store.

Based on announcements from the official websites of relevant shops, confectionery stores at F3 and F4 were closed during the COVID-19 pandemic in 2020 due to stagnation and a decline in passengers. At the other four stations, shops in the concourse were closed or replaced before 2018, which is considered unrelated to the COVID-19 outbreak.

3) Changes in shop usage and influencing factors

We selected the other seven stations that had no changes in concourse shops for further comparative research between 2008 and 2021. We analyzed shop usage in the concourses at these seven stations. As shown in Table 2-2, we set the investigation date based on our previous study. We kept the investigation date consistent with the previous research, ensuring the weekdays matched as well. Additionally, we examined the locations of the shops relative to the ticket gates. There are two types of locations: shops at five stations are directly in front

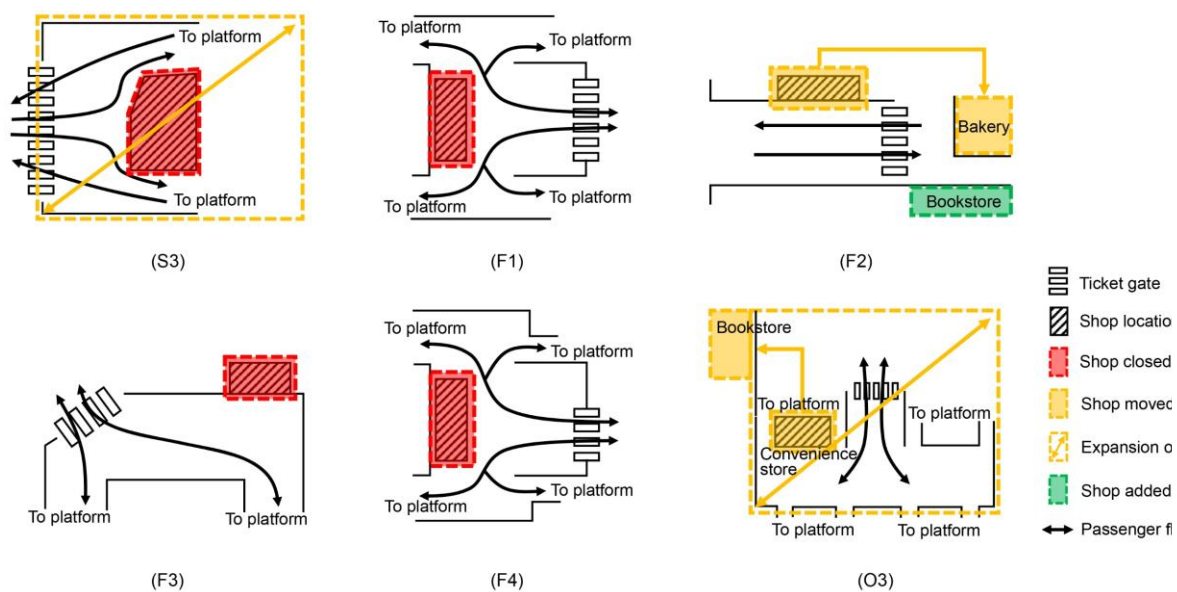


Figure 2-4 Changes in concourse shops in 6 stations

Table 2-1 Information of changes in 6 stations

Station	Changes in concourse	Time of changes	Shops in concourse (2010)	Shops in concourse (2022)
S3	The concourse was expanded and the convenience store in concourse was moved outside of concourse	2011-2014	Convenience store	None
F1	The concourse was redecorated and the bakery in concourse was closed	2015-2018	Bakery	None
F2	The bakery in concourse was moved outside of concourse; A new bookstore was set outside of concourse	2015	Bakery	None
F3	The confectionery store in concourse was closed	2020	Confectionery store	None
F4	The confectionery store in concourse was closed	2020	Confectionery store	None
O3	The bookstore was replaced by a convenience store; A new bookstore was opened inside the new east concourse	2013-2014	Bookstore	Convenience store

of the ticket gates, while the other two are on the side of the ticket gates. The shops at four stations are convenience stores.

Based on the daily passenger counts and shop usage at each of the seven stations, there was a noticeable decline in passenger numbers across all stations, with decreases ranging from 16.42% to 25.96%. Meanwhile, shop use dropped significantly at six stations, with declines between 25.00% and 88.24%. Additionally, there was a 7.69% increase in restaurant users at Akashi Station; however, due to the lower overall user numbers, we cannot determine whether COVID-19 affected shop usage differently across categories.

We analyzed passengers and users based on station and shop locations. First, as shown in Table 2-3, there was a decline in both passenger and shop users at downtown and suburban stations. The decrease was greater at downtown stations compared to suburban ones. Shop locations in the concourse reveal higher rates of decline for both passengers and shop users at stations where shops are located beside the ticket gate rather than in front of it.

Table 2-2 Information of 7 stations without change

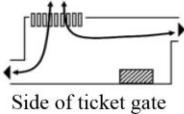
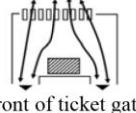
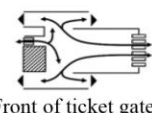
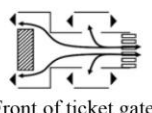
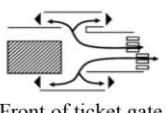
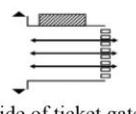
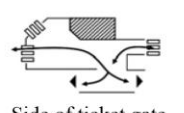
Station	Location of station	Investigation date		Categories of shops	Location of shops in concourse	Decline rate in passengers	Decline rate in users
		2008	2022				
S1	Downtown	12.08 (Thur.)	12.11 (Thur.)	Bakery	 Side of ticket gate	25.96%	88.24%
S2	Downtown	11.08 (Tues.)	11.11 (Tues.)	Convenience store	 Front of ticket gate	22.34%	25.00%
S4	Downtown	11.25 (Fri.)	11.28 (Fri.)	Convenience store	 Front of ticket gate	25.90%	45.95%
S5	Suburb	11.02 (Wed.)	11.05 (Wed.)	Convenience store	 Front of ticket gate	16.42%	25.00%
S6	Downtown	11.18 (Fri.)	11.14 (Fri.)	Convenience store	 Front of ticket gate	19.25%	47.37%
O1	Suburb	11.22 (Tues.)	11.25 (Tues.)	Restaurants	 Side of ticket gate	18.07%	-7.69%
O2	Suburb	11.22 (Tues.)	11.25 (Tues.)	Food store Drug store	 Side of ticket gate	25.01%	61.11%

Table 2-3 Comparison of decline rate of average daily passengers and shop users based on station locations and shop locations

Categories		Rate of average daily passenger decline	Rate of shop user decline
Station location	Downtown	23.36%	51.64%
	Suburb	19.83%	26.14%
Shop location	Front of ticket gate	20.98%	35.83%
	Side of ticket gate	23.01%	47.22%

2.4 Compact of COVID-19 on Passenger and Shop Usage

We performed correlation analyses to examine the relationship between COVID-19 and store usage. First, we measured the impact of COVID-19. According to related studies, the

change in the daily passenger numbers indicates the effect of COVID-19. We conducted all correlation analyses at seven stations that did not experience any changes.

According to the investigation, there are two types of station locations—downtown and suburban—as well as two kinds of shop locations in the concourse: in front of the entrance and on the side of the entrance. We used linear regression analysis to examine the relationship between passenger decline, user decline, and the locations of stations and shops. The independent variables are station and shop locations. The dependent variables are the rate of passenger decline and the rate of shop user decline.

We conducted binary variable regression analyses of the station and shop locations. As shown in Table 4 and Table 5, all four Sig. Values were greater than 0.05. The results indicate

Table 2-4 Binary variable regression analyses of passenger decline rate

Modelo	Coefficientes no estandarizados		Coefficientes estandarizados	t	Sig.
	B	Desv. Error	Beta		
(Constante)	0.212	0.022		9.639	0.001
1-downtown; 2-suburb	0.053	0.029	0.715	1.835	0.140
1-front ; 2-side	-0.042	0.029	-0.573	-1.470	0.215

Dependent Variable: Rate of passenger decrease

Table 2-5 Binary variable regression analyses of shop user decline rate

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	0.350	0.189		1.855	0.137
1-downtown; 2-suburb	0.366	0.247	0.641	1.481	0.213
1-front ; 2-side	-0.266	0.247	-0.467	-1.078	0.342

Dependent Variable: Rate of shop user decrease

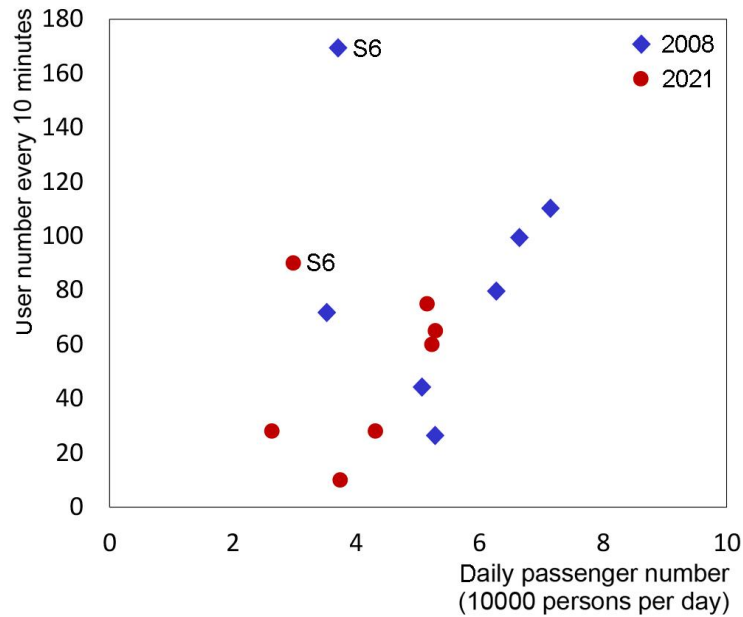


Figure 2-5 Relationship between daily passenger number and user number of shops in 7 stations (2008 and 2021)

no significant difference in how station and shop location affect passenger and shop user decline.

To confirm the correlation between the passenger numbers and shops, we analyzed the relationship between the passenger numbers and shop users at seven stations. As shown in the scatter plot in Figure 2-5, there appears to be a linear regression relationship between the passenger numbers and users for both 2008 and 2021. To verify this hypothesis, we conducted a paired-samples t-test.

We examined not only the overall passenger numbers and users but also the changes in these figures. We created five pairs to perform a paired-sample t-test and bivariate correlation analysis.

- 1) the passenger numbers in 2008 and the number of people using shops in 2008;
- 2) the passenger numbers in 2021 and the number of people using shops in 2021;
- 3) the decline in passenger numbers and user counts;
- 4) the decline rate in the passenger numbers and in the number of shop users;
- 5) the ratio of passengers to shop users in 2021 compared to 2008.

Table 2-6 shows the results of five pairs of tests. The values of pairs 1, 2, and 3 were below 0.05, indicating significant differences between the two variables in each pair. The results of pair 4 and 5 suggest fewer differences between the variables in each pair. Specifically, the results of pair 4 and 5 indicate less distinction between the rate of decline in passenger

numbers and the decrease in user numbers. Due to the limited samples, another correlation analysis hinted at a potential link between the variables in pair 4 and 5 (Table 2-7).

In addition to analyzing the overall correlation, it is important to examine the differences in how the correlation varies between the overall change in passengers and shop users across different categories. We conducted two other comparative studies on user classification based on the time of day and boarding or alighting between 2008 and 2021. We focused on analyzing the relationship between the rate of passenger decline, the time period, and boarding or alighting progress.

Based on the results (Figures 2-6 and 2-7) of the time period, we observed a sharp decline in the number of users in the morning and a significant increase in users at night. Additionally, the number of users during noon was the lowest, similar to 2021 compared to 2008. This suggests that more passengers preferred to use shops on their way home from work rather than after the COVID-19 pandemic. From the boarding and alighting data, we also noticed a slight decrease in the average number of users during boarding and a slight rise in alighting.

Table 2-6 Paired samples test of 5 pairs

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Number of passenger - number of shop users (2008)	-80.6429429	48.1414285	18.1957497	-125.1663384	-36.1195473	-4.432	6	0.004
Pair 2	Number of passenger - number of shop users (2021)	-45.9571000	28.5988234	10.8093392	-72.4066002	-19.5075998	-4.252	6	0.005
Pair 3	Passenger decline - user decline	-34.6858429	26.3445380	9.9572994	-59.0504768	-10.3212089	-3.483	6	0.013
Pair 4	Rate of passenger decline - rate of user decline	-0.1714000	0.2485562	0.0939454	-0.4012762	0.0584762	-1.824	6	0.118
Pair 5	Ratio of 2021 to 2008 (passengers)-ratio of 2021 to 2008 (users)	0.1886143	0.2777511	0.1049800	-0.0682626	0.4454912	1.797	6	0.123

Table 2-7 Correlation analysis of 5 pairs

	Pair 1	Pair 2	Pair 3	Pair 4	Pair 5
Pairs for testing	Number of passenger - number of shop users (2008)	Number of passenger - number of shop users (2021)	Passenger decline - user decline	Rate of passenger decline - rate of user decline	Ratio of 2021 to 2008 (passengers) - ratio of 2021 to 2008 (users)
Sig. (2-tailed)	0.833	0.599	0.832	0.065	0.066

Correlation is significant at the 0.05 level (2-tailed).

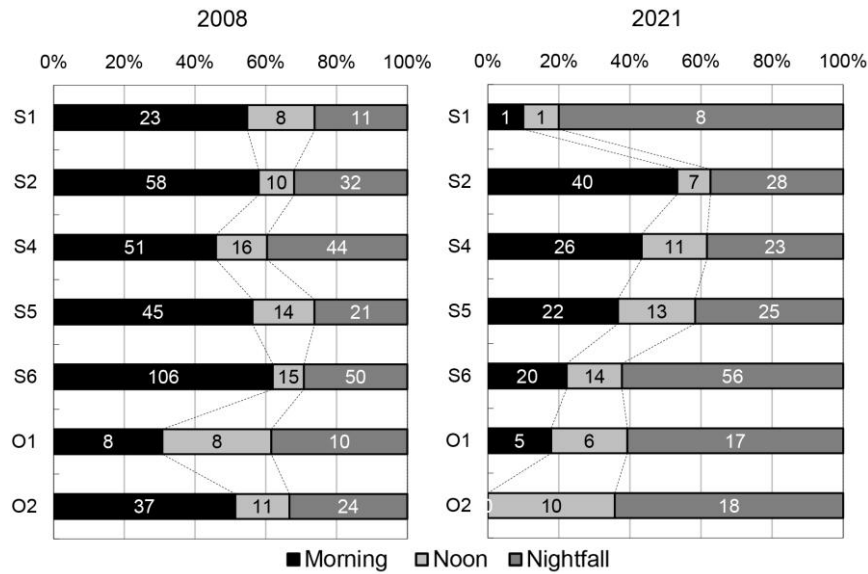


Figure 2-6 User proportion of three time periods in 7 stations (2008 and 2021)

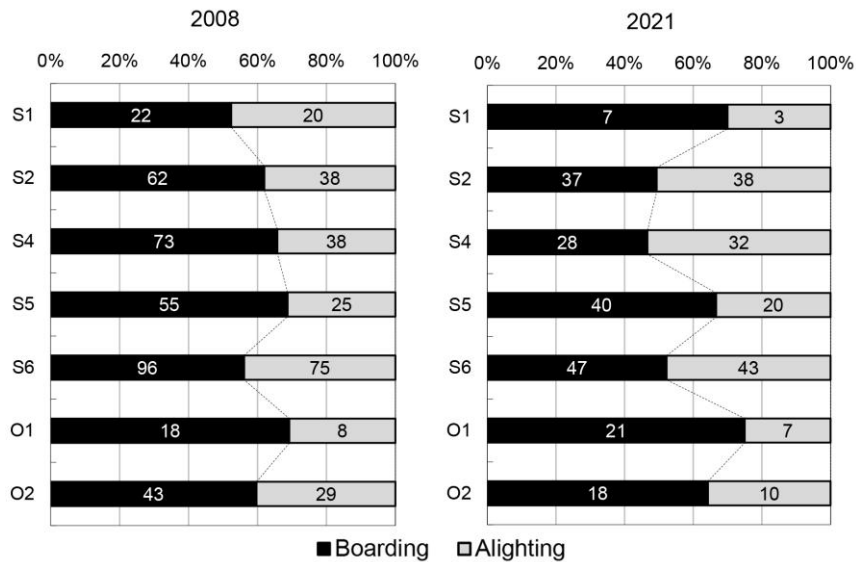


Figure 2-7 User proportion of boarding and alighting in 7 stations (2008 and 2021)

To examine the influence of COVID-19 on changes in users during different time periods and processes, we conducted further correlation analysis between the decrease in the passenger numbers and the decrease in the number of users based on time period and boarding-alighting. The results in Table 2-8 show that the 2-tailed significance values for the nightfall boarding process are below 0.05. This indicates a significant correlation between the rate of decrease in the number of users in the nightfall period and the boarding process, with a decline in the passenger numbers.

Conversely, convenience stores are located at 5 out of the 8 stations with shops in the concourse, which are frequently used by passengers. Table 2-9 displays the significance values for the relationship between passenger numbers and convenience store usage. The results also show a significant correlation between the passenger rate and the rate of convenience store users.

2.5 Discussion

Under the influence of COVID-19, the number of people in public places dropped significantly. Public facility usage also declined, and social distancing measures between people in public increased. This has also been observed in pedestrians, stations, campuses (Saio, 2022), residences (Guo et al., 2022), and commerce across Japan. Changes in passenger numbers and store activity caused by COVID-19 were illustrated through our research of 13 stations operated by the West Japan Railway Company.

The passenger numbers at the 12 stations dropped significantly from 2020, when COVID-19 emerged. The pandemic is seen as the main reason for the decline in passengers, as citizens in Japan reduced their travel during COVID-19. However, according to the investigation, station concourse facilities were less affected by the pandemic. We observed changes at six stations, with only two of them being caused by COVID-19. Most of the changes in concourse facilities resulted from renovations and expansions at the stations before the COVID-19 outbreak.

The locations of stations and types of shops had different effects on passengers routes and shop usage at concourses (Kido et al., 2009; Suwa et al., 2009; Yokota et al., 2011). In this

Table 2-8 Correlation analysis of time period and boarding-alighting

Rate of user decline		Time period			Boarding	Alighting
		Morning	Noon	Nightfall		
Rate of passenger decline	Sig. (2-tailed)	0.327	0.187	0.016	0.026	0.279

Correlation is significant at the 0.05 level (2-tailed).

Table 2-9 Correlation analysis between passenger and use of convenience stores

Variate A	Categories					
	Passenger number (2008)	Passenger number (2021)	User number of convenience store (2008)	Passenger decline	Rate of passenger decline	Ratio of 2021 to 2008 (passengers)
Variate B	User number of convenience store (2008)	User number of convenience store (2021)	User number of convenience store (2021)	User decline of convenience store	Rate of user decline of convenience store	Ratio of 2021 to 2008 (users of convenience store)
Sig. (2-tailed)	0.087	0.332	0.267	0.224	0.025	0.025

Correlation is significant at the 0.05 level (2-tailed).

study, we observed a larger decrease in both passengers and shop users at downtown stations and shops beside the ticket gate. However, the results of the binary variable regression analyses indicate no significant difference in the impact of station location and shop type on passenger and user decline during COVID-19.

Although there is a linear regression relationship between the daily passenger numbers and the number of shop users in both 2008 and 2021, the correlation analysis shows no significant connection. However, examining the decline rate and the ratio of 2021 to 2008, we found weak correlations. Further analysis considering different time periods and the boarding-alighting process revealed a more significant link between passenger decline and night-time user decrease than with morning and noon, and a stronger correlation between passenger decline and boarding user decrease than with alighting users. This indicates that COVID-19 had a greater impact on reducing shop usage among night-time and boarding passengers.

Additionally, we observed a significant correlation between the decline in passengers and the reduction in the use of convenience stores, which are often used by passengers. At the same time, the percentage of users during nightfall and the boarding process increased at most stations in 2021. Therefore, the more users there are, the greater the impact on users during COVID-19.

2.6 Conclusion

We compared shop usage before and after the COVID-19 outbreak at concourses in 13 stations operated by the West Japan Railway Company. We repeated the investigation following a previous study we conducted in 2008. We found that the passenger numbers decreased at 12 stations and that shop numbers changed at six stations. Shops at two stations closed in 2020 due to the COVID-19 pandemic. We focused on analyzing the changes in passenger and shop user numbers across seven stations without changing the shops.

First, the location of the station and shop in the concourse showed no difference in their influence on changes in the passenger numbers and users. Second, we observed no significant correlation between the passenger numbers and the number of shop users, or between the decrease in passengers and the decrease in shop users. In contrast, we noted significant correlations between decline in passengers and users during nighttime and among boarding passengers. Additionally, there is a correlation between the decline in passengers and users at convenience stores in five stations.

The COVID-19 pandemic significantly affected both the passenger numbers and shop usage at the concourses of stations operated by the West Japan Railway Company. The

impacts of COVID-19 on shop use are demonstrated from three aspects: a decline in the total passenger numbers at each station, a notable effect on shop visitors during nighttime and boarding times, and an impact on users of convenience stores inside the concourse. Furthermore, this suggests that COVID-19 had a more substantial impact on shop use and during periods with more users.

This study explores how passengers' behaviors in railway station public spaces have changed after COVID-19, with a focus on shop usage, by comparing re- and post-COVID-19 results. Railway stations in Japan serve as typical public spaces for examining COVID-19's impact on daily activities and facility use. Consequently, we believe this study offers a valuable perspective for understanding behavioral changes in public spaces influenced by COVID-19. Additionally, the methods used in behavioral studies and facility usage analysis can be applied to other public facilities with similar functions, not only in Japan but also across other Asian countries, especially those with transportation hubs featuring highly functional elements, such as South Korea, Hong Kong, Singapore, Taiwan, and mainland China.

We identified the objects examined in this study based on our previous research on 13 stations operated by the West Japan Railway Company in 2008. The content of the comparative study also solely relied on the earlier results we obtained. This study has several limitations that must be acknowledged. First, the number of objects was limited to better understand additional characteristics of passengers' behavior and shop usage after COVID-19. Second, there is a significant gap between the two periods. We chose seven stations that experienced no changes in their shops during the study period. Passenger behavior has been shown to change somewhat. The shopping habits of passengers at stations are also believed to have shifted over the past 10 years. To account for these factors, more cases involving different railway lines, locations, and shop types should be examined in future research to verify the generality of our findings.

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CHAPTER 3 STUDY ON BEHAVIORS AT THE REST SPACES IN THE CONCOURSES OF THE OSAKA MONORAIL

3.1 Introduction

3.1.1 Social Background

The COVID-19 pandemic, which started in 2020, has continued worldwide for more than three years. Due to the virus's high infectivity and severity, most countries enforced strict policies to prevent spread in public places. Health authorities around the world recommended measures such as avoiding large gatherings, maintaining physical distance, and wearing face masks. In Japan, government guidelines focused on avoiding the “Three Cs” (closed spaces, crowded places, close-contact settings) and keeping at least a 2-meter distance from others while wearing masks in public. These extraordinary measures significantly disrupted daily life and mobility patterns.

One of the most affected areas was public transportation and related facilities. Transit ridership dropped sharply worldwide during the early waves of COVID-19, with studies showing declines of 40–60% in many urban rail systems as people avoided non-essential travel. Even as infection rates fluctuated, public transport use stayed low and changed in nature. Researchers in Japan and elsewhere saw that large city railway stations experienced especially steep drops in passenger numbers, while smaller or suburban stations saw more moderate impacts and recovered more quickly. By early 2022, authorities started relaxing restrictions on public gatherings to balance economic activity with health concerns. However, ridership and travel habits did not immediately return to pre-pandemic levels. Many habits and precautions formed during the pandemic continued, still affecting how people move and use public spaces. For example, the rise of remote work and online activities led to ongoing reductions in daily commuting, and many people remained cautious about crowded indoor places. Overall, the effects on rail systems included not just an initial drop in passengers but also lasting changes in how travelers interact with station spaces – such as less use of station amenities, shorter stops during trips, and increased awareness of hygiene and personal space in crowded areas.

This study builds upon previous research on railway station concourses in West Japan, conducted before the pandemic. Earlier studies in 2008 and 2010 examined passenger behaviors in station concourses, especially resting patterns and facility use. Those studies found that the layout and type of concourse facilities greatly influenced where and how passengers paused within the concourse. Additionally, behaviors like sitting, waiting, and using amenities exhibited distinct characteristics based on factors such as gender, time of day, age group, and group size. These baseline findings demonstrate that even during normal times, who the passengers are and how the concourse is designed can affect usage patterns.

Based on that foundation, the present work is the first to compare passenger behavior and facility use in Osaka Monorail station concourses before and after the COVID-19 pandemic. Specifically, this case study examines rest areas within the concourse to understand how the pandemic may have changed passenger stay habits. By comparing data from the pandemic to data from 2022, we seek to clarify the pandemic's effects on who uses these indoor public spaces, how long and in what ways they stay, and which facilities they choose. The goal is to highlight changes in concourse usage caused by COVID-19, helping to design more adaptable and user-focused railway station spaces in the future.

3.1.2 Related works

Station concourses are a unique type of urban indoor public space where streams of transit users converge. Recent research on public space usage during the pandemic shows that transit stations and plazas experienced notable behavioral changes. In many cases, passengers spent less time lingering and moved differently through these areas under COVID-19 conditions. For example, one simulation study of a major railway hub compared concourse traffic before and during the pandemic and found that passengers who purchased tickets via smartphone or other contactless methods could pass through the concourse with minimal queuing, while those buying tickets on-site formed queues and spent longer in the concourse. During the COVID-19 pandemic, a much higher share of travelers bought tickets in advance to avoid crowds, leading to significantly shorter dwell times in the station. In practice, transit operators and planners worldwide began recommending interventions like contactless ticketing, one-way circulation paths, and widened corridors to promote social distancing and reduce unnecessary dwell time in stations. These measures aimed to make station circulation more “frictionless” and safer during the pandemic, allowing commuters to move quickly and with minimal close contact.

Beyond ticketing and circulation, studies of crowd dynamics reveal broader shifts in mobility patterns driven by fears of contagion. With increased anxiety about infection, travelers tend to avoid crowded areas and seek routes or waiting spots that offer more separation from others. An analysis from one transit hub showed that high-density zones of the station became underused as people moved to emptier corners or spread out along passageways. Similarly, a pedestrian flow study in a Japanese train station observed that while average walking speeds remained relatively unchanged before and after the pandemic, the interpersonal distance maintained between individuals increased—people naturally kept farther apart and avoided close contact while walking. This avoidance behavior has been widely documented across various public settings: individuals shorten their stays and minimize direct interactions whenever possible to reduce risk. In summary, fear of contagion not only affected whether people traveled but also how they navigated space during their trips. Travelers preferred routes and behaviors that felt safer, even if it meant walking longer distances or skipping usual stopping points, and many became less inclined to linger or socialize casually in transit environments.

Concourse layout and amenities also influence these behavioral shifts. Before the pandemic, transport studies showed that amenities like shops, kiosks, benches, or vending machines in a concourse can affect where passengers stop and for how long. These facilities traditionally attract travelers to pause—such as to buy a newspaper or rest on a bench—shaping typical flow and stay patterns. However, during the pandemic, many of these high-touch or shared amenities experienced sharp declines in use. Observational reports noted that vending machines, newsstands, and public seating at stations were much less frequented during COVID-19. Users now prioritize spaciousness, ventilation, and cleanliness when choosing where to stand or sit. In retail settings, evidence also suggests that post-pandemic consumers value a location's spatial features more when deciding whether to enter or stay. As a result, planners and designers argue that station concourses must adapt to support distancing needs and new user preferences. Flexible layouts are often suggested—for example, reconfigurable or spread-out seating, clearer one-way pedestrian flow schemes, and plenty of open spaces to reduce bottlenecks. These design strategies, widely discussed in literature, aim to keep public transit spaces functional and inclusive while emphasizing health and safety.

In summary, the existing research on pandemic-era public space use highlights several themes relevant to concourse spaces: overall mobility demand has changed, avoiding close contact has become a key behavior, spaces have been repurposed or de-densified to allow for distancing, and there is a call for responsive design interventions to support safe use of transit

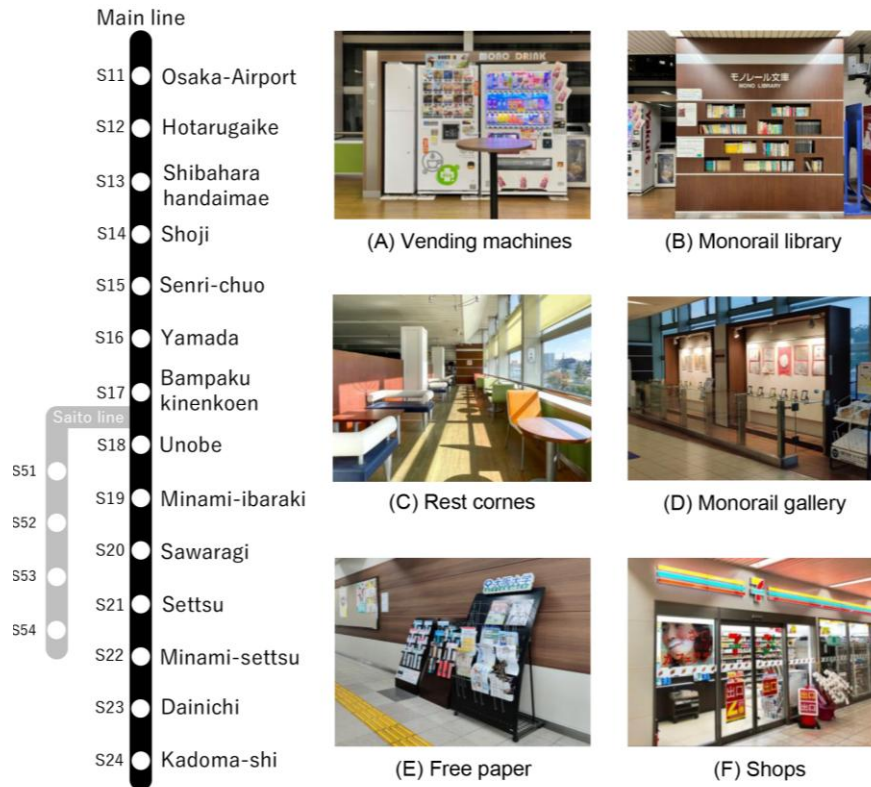


Figure 3-1 Eighteen stations of Osaka Monorail and images of space for rests in the concourse

facilities. These insights offer important context for understanding how the Osaka Monorail concourses were reshaped by COVID-19, and they shape the expectations and hypotheses of this study.

3.2 Method of study

Firstly, this study surveyed the 14 station concourses of the Osaka Monorail main line, focusing on the spaces and facilities within the concourse (Figure 3-1). There are two main spaces in the concourse: the rest space and the art space. Most concourse rest spaces include vending machines, monorail libraries, and rest corners. Art spaces include a monorail museum or a gallery displaying small-scale artworks. Other facilities include free papers and shops inside or outside the concourse.

Secondly, as shown in Table 3-1, surveys on passenger behaviors in concourses were conducted at 10 stations in August 2022. Station S17 was excluded because its concourse space was different. Stations S14, S16, and S23 were also excluded due to the very small number of users compared to other stations.

Table 3-1 Investigation information of ten stations in 2022

Serial number of stations	Date (year/month/day/week/weather)	Survey contents
S11, S12, S13, S15, S18, S19, S20, S21, S22, S24	S11: 2022.08.18 (Thur.) Clear	(1) Facilities arrangement in concourse: Recording location of facilities each station.
	S12: 2022.08.08 (Mon.) Cloudy	
	S13: 2022.08.15 (Mon.) Clear	(2) Recording of passenger flow: Recording passenger flows in concourses, both boarding and alighting. The starting point, ending point, and walking direction are also marked. The number of passengers is calculated through videos.
	S15: 2022.08.09 (Tues.) Cloudy	
	S18: 2022.08.26 (Fri.) Cloudy	(3) Recording staying behaviors: Location, duration, and basic information about passengers.
	S19: 2022.08.11 (Thur.) Clear	
	S20: 2022.08.16 (Tues.) Cloudy	(4) Facility utilization: Number of facility usage in the concourse of passenger flows.
	S21: 2022.08.23 (Tues.) Cloudy	
	S22: 2022.08.25 (Thur.) Cloudy	
	S24: 2022.08.19 (Thur.) Clear	

The survey dates for each station were set based on prior investigations in 2008 and an additional survey of S15 in 2010, to ensure that each survey was conducted under similar climate and weather conditions.

Based on survey results before and after the COVID-19, we conducted comparative studies in three steps.

- 1) Study on changes in passenger numbers and stay behaviors before and after COVID-19.
- 2) Comparative study on characteristics of stay behaviors in concourses before and after COVID-19.
- 3) Comparative study on characteristics of passenger flows in concourse and temporary facility utilization before and after COVID-19.

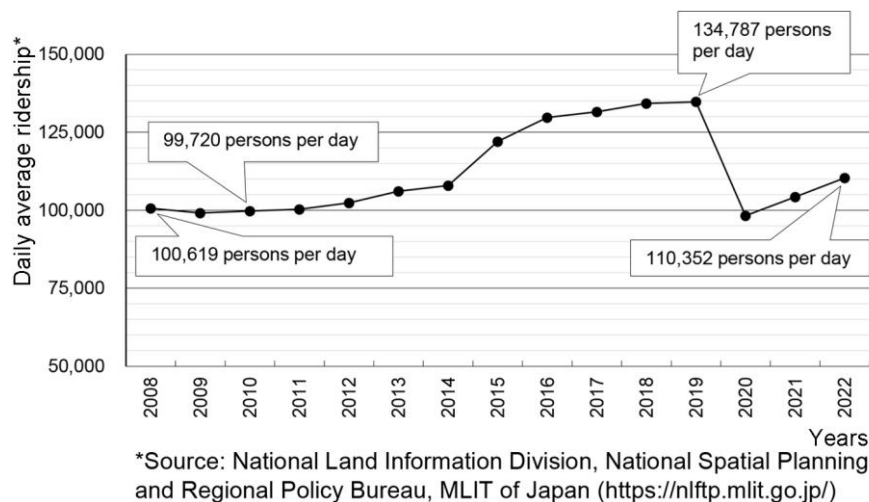
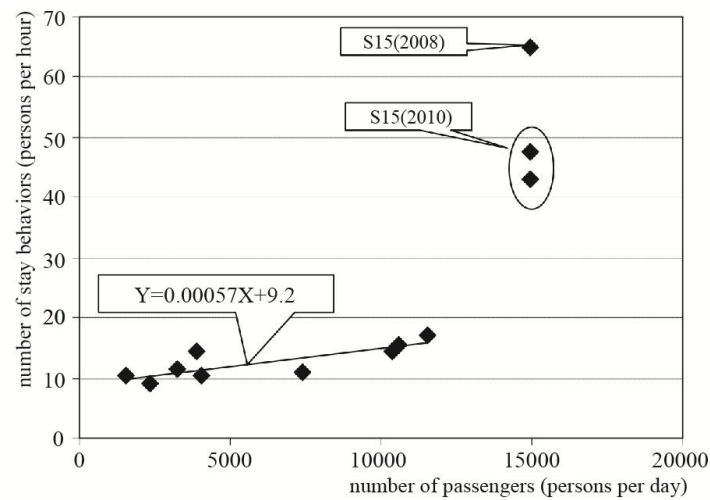


Figure 3-2 Daily average ridership from 2008 to 2022

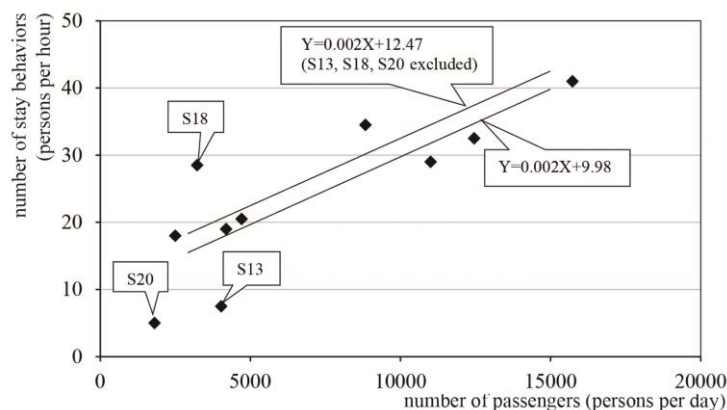
3.3 Influence of the COVID-19 pandemic on number of stays in concourse

Figure 3-2 shows the total daily ridership of Osaka Monorail from 2008 to 2022. The number remained around 100,000 from 2008 to 2011 and steadily increased from 2012 to 2019, reaching nearly 135,000 in 2019. After that, the number dropped sharply to about 100,000 in 2020 due to the COVID-19 pandemic. Ridership gradually rebounded after 2021, reaching 110,352 in 2022.

Similar to the previous study in 2008, the stays in rest areas in the concourse are recorded at 10 stations along the Osaka Monorail Main Line for two hours, from 5 PM to 7 PM. Passengers observed sitting or remaining in rest areas for more than 1 minute are counted as stays in the concourse.



(A) 2008



(B) 2022

Figure 3-3 Linear regression between passenger numbers and number of stays

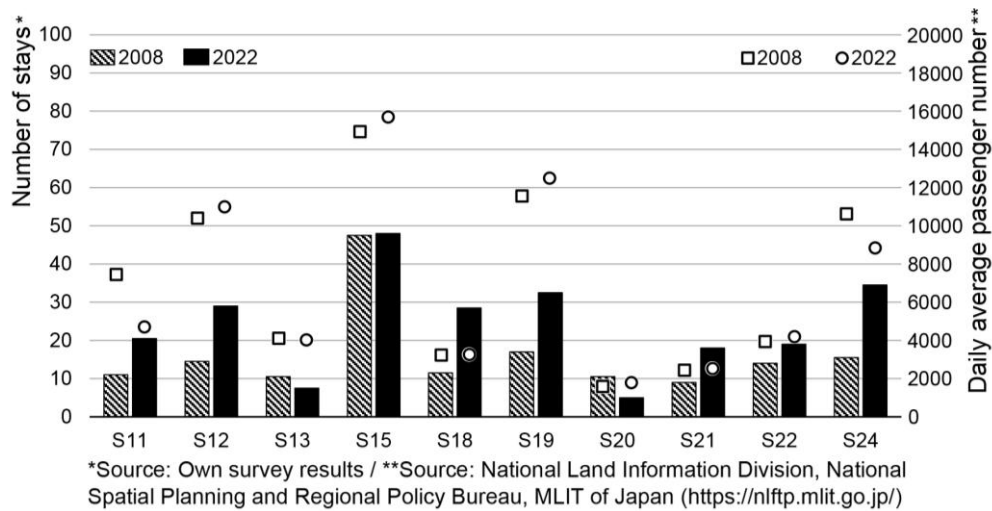


Figure 3-4 Daily average passenger number and numbers of stays in 10 stations of Osaka Monorail in 2008 and 2022

In the previous study, we used a linear regression analysis, we found a correlation between passenger numbers and the number of stays in Osaka Monorail station concourses, as shown in Figure 3-3 (A). Figure 3-3 (B), based on the 2022 survey, also displays a correlation between passenger numbers and stays. We noticed a steeper slope in the 2022 equation compared to 2008, indicating that changes in passenger numbers more significantly affected the number of stays in 2022 after the COVID-19 pandemic.

However, as shown in Figure 3-4, when analyzing the changes in daily average passenger numbers and the number of stays in 2008 and 2022, the scale of change in the number of stays did not match the change in passenger numbers: increases in passenger numbers are seen at 6 stations, while increases in the number of stays are observed at 8 stations. At stations S11 and S24, which are starting stations, even though the passenger numbers declined, the number of stays increased in 2022.

The analysis clearly indicates that stations with more passengers tend to have more stays in the concourse. However, since passenger numbers in 2022 have already returned to pre-pandemic levels and are similar to those in 2008, comparing the two years doesn't allow us to determine the relationship between changes in passenger numbers and stays. Therefore, it is also not possible to assess the pandemic's impact on the number of stays.

3.4 Influence of the COVID-19 pandemic on stay behaviors in rest spaces

We aimed to understand how the COVID-19 pandemic affected stay behaviors by comparing the changes in the characteristics of passengers remaining in the concourse. We used five indicators: gender composition, boarding and alighting, group size, and length of stay.

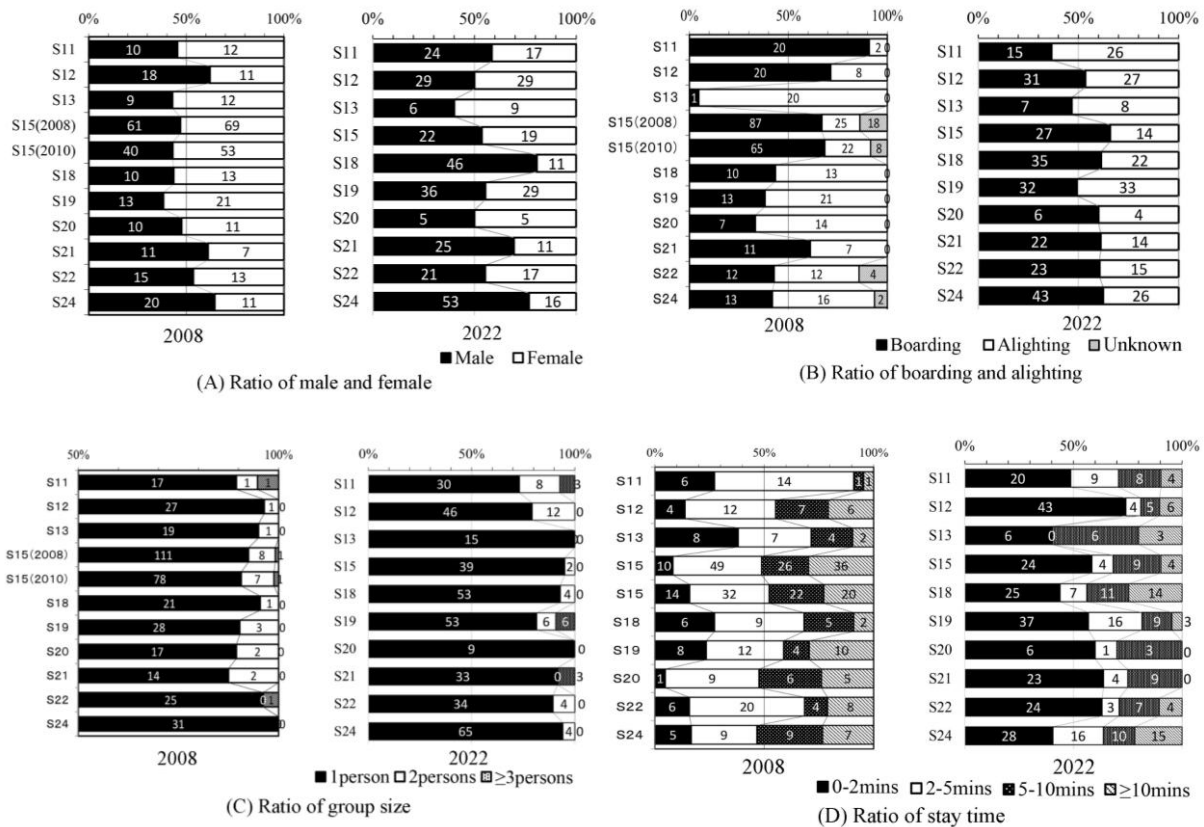


Figure 3-5 Classification analysis of stay behaviors

Figure 3-5 shows the comparison results between the two years. First, the proportion of male passengers was higher in 2022 than in 2008. Second, the proportions of boarding and alighting passengers varied greatly at each station in the 2008 survey, while in the 2022 survey, the proportions were nearly equal at each station. Third, passengers traveling alone in the concourse had the largest group size proportion in both 2008 and 2022. Additionally, the proportion of passengers with a duration of less than 2 minutes increased in 2022 compared to 2008.

Based on the analysis above, it is clear that, influenced by the pandemic, passengers are more likely to shorten their stay in rest areas, and the decline in the proportion of female passengers may indicate a decline in the number of non-commuting travelers, such as housewives. Since the proportion of passengers traveling alone was the highest in both years, it is hard to determine whether the pandemic affected the group size of stays.

3.5 Influence of the COVID-19 pandemic on passenger flows in concourses

In addition to stay behaviors, boarding and alighting passenger flows are observed in concourse passageways, some of which involve temporary facility utilization. We conducted

comparative studies between two years, aiming to elucidate the impact of the COVID-19 pandemic on passenger flow behaviors in the concourse.

Consistent with the classification used in previous studies, we selected four stations to analyze passenger flows, as shown in Table 3-2: S11, S15, and S19 were selected as stations with passageways and facilities on both sides, while S21 was selected as a station with passageways on both sides and facilities on one side. All four stations share a similar spatial structure, characterized by relatively wide passageways centered around stairs and escalators.

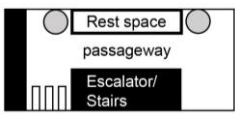
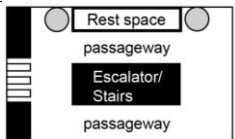
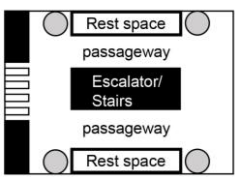
1) Changes in characteristics of passenger flows in concourses

We recorded passenger numbers and flow directions in each concourse during boarding and alighting from 5 PM to 7 PM. As figures in Table 3-3 show, the arrows of lines represent the direction of passenger flow, while the thickness of the lines indicates the number of passengers.

Firstly, it can be observed that most passengers prefer using the escalator between the platform and the concourse, even when stairs are nearby, as they tend to pass by the stairs in favor of the escalator. However, our observations show a slight increase in stair usage when the concourse is crowded with alighting passengers during train arrivals and departures.

Secondly, when alighting, passengers tend to turn to the side where there is no boarding escalator. Additionally, overall, we observed no significant difference in passenger flow characteristics between 2008 and 2022.

Table 3-2 Three types of concourses

Types of concourses	Diagram of plan	Classification of stations	Target of Investigation
Single sided passageway-single sided facilities		S12, S13	—
Double sided passageways-single sided facilities		S20, S21, S22	S21
Double sided passageways-double sided facilities		S11, S15, S18, S19, S24	S11, S15, S19

 Facilities

2) Characteristics of temporary facility using

Simultaneously, behaviors involving temporary breaks and use of facilities in the concourse during boarding and alighting flows were recorded. According to the investigation, the Monorail drink stations (M), vending machines (V), free paper corners (F), Monorail libraries (L), and benches (B) are the five most frequently used facilities by passengers. The histograms in Table 3-3 show the number of passengers temporarily using facilities at each station.

Firstly, we can conclude that alighting passengers who stop in rest spaces and temporarily use facilities are fewer than boarding passengers. Secondly, compared to the results in 2008,

Table 3-3 Characteristics of passenger flows and temporary facility utilization in four stations

Stations		Boarding	Alighting	Temporary facility usage
S11	2008			
	2022			
S15	2008			
	2022			
S19	2008			
	2022			
S21	2008			
	2022			

Mono museum / gallery
 Escalator
 Stairs
 Toilets

Rest corner
 Bench
 Free paper
 Mono drink
 Mono library
 Vending machine

Boarding users
 Alighting users

0-50 50-100 100-300 300-500 >500 persons

there was a decrease in the total number of users in 2022. The Monorail drinks (M) were the most frequently used facility at four stations, while vending machines (V) were the second most used, mainly at three stations.

In summary, the COVID-19 pandemic significantly impacted the number of temporary facility users, particularly those boarding. However, there is insufficient evidence to prove that changes in the proportion of facilities used are related to the pandemic's influence. Additionally, the results indicate no correlation between changes in passenger flows and temporary facility usage.

3) Influence of changes in facilities on behaviors in concourse

Studies in East Japan railways by other scholars showed that setting shops inside concourses and along passages will reduce the speed of passenger flow and increase stays.

Compared to the 2008 survey results, changes in passenger flows seem to be linked to modifications in the concourse facilities. As shown in Table 3-4, we analyzed the differences in the facilities at 10 station concourses in 2022 compared to the 2008 results.

In the concourse of S11, compared to 2008, the rest spaces in 2022 remained unchanged. However, the number of vending machines on the north side decreased, and a monorail library was added near the rest space on the south side. Different from the situation in 2008, when more boarding passengers used the north passageway to take the escalator to the platform, the 2022 survey showed that, even though the up escalator is on the north side, the number of boarding passengers on the north and south passageways was roughly the same.

Table 3-4 Changes of facilities in the concourse of 10 station in 2008 and 2022

Stations	Shops in front of the entrance				Rest spaces				Art spaces					
	Convenience stores		Shops		Vending machines		Rest Corners		Monorail library		Monorail museum		Monorail Gallery	
	2008	2022	2008	2022	2008	2022	2008	2022	2008	2022	2008	2022	2008	2022
S11	—	—	—	—	○	▼	○	○	—	▲	—	—	—	—
S12	—	▲	—	▲	○	○	○	○	—	▲	○	▼	○	○
S13	—	—	—	—	○	○	○	○	—	▲	○	▼	—	—
S15	○	○	—	—	○	○	○	▼	○	○	○	▼	○	▼
S18	—	—	—	—	○	○	○	○	○	○	○	○	—	—
S19	—	—	○	▼	○	▼	○	▼	○	○	○	○	—	—
S20	—	—	○	▼	○	○	○	○	○	○	○	○	—	—
S21	—	—	○	▼	○	○	○	○	○	○	○	○	—	—
S22	—	—	○	▼	○	○	○	▲	—	—	○	○	—	—
S24	○	○	—	—	○	○	○	○	○	○	○	○	○	○

○ : Existing at 2010 and 2022

▲ : Added before 2022

▼ : Removed or reduced before 2022

— : Not exist

In the concourse of S15, a café opened on the north side in the 2022 survey, replacing the rest space, vending machines, and the Monorail gallery. As a result, more passengers used the south side passageway to access the escalator to the platform in 2022 compared to 2008. Conversely, the 2022 survey showed more alighting passengers from the platform using stairs down to the passageway on the north side compared to 2008.

In the concourse of S19, although shops replaced the rest space and vending machines on the west side in the 2022 survey, passenger flow did not significantly change between the two years. In the S21 concourse, aside from changes in passenger numbers, we observed no differences in facilities or passenger flow characteristics between the two years.

After comparing passenger flows and temporary facility usage over two years, considering the facility changes in the concourse, there is no clear evidence that the facility modifications affected passenger flows and temporary facility use. Instead, it suggests that the route chosen by boarding and alighting passengers mainly depends on the locations of escalators and stairs. Additionally, the decline of temporary facility use in the concourse may be related to the shorter stay time after the COVID-19 pandemic.

3.6 Discussion

The case of the Osaka Monorail concourses confirms several pandemic-related patterns reported in the broader literature. First, regarding overall ridership and stay durations: as expected, passenger volumes dropped sharply during the peak of COVID-19 (especially in 2020–2021). By 2022, total concourse use in our surveyed stations had recovered to near pre-pandemic levels, but this was mostly because the busiest stations regained their traffic; on an individual level, people were generally spending less time in the concourse than before. Our comparative data show that a much larger percentage of travelers limited their stops to under 2 minutes in 2022 compared to 2008. This matches findings from other studies indicating that travelers cut down on non-essential lingering during the pandemic. Even while using transit, most people preferred to keep their station dwell time as short as possible, echoing the “quick passage” behavior noted in simulation studies. Essentially, passengers in the post-COVID era prioritize rapid movement with minimal contact or delays, a direct reflection of the widespread risk-avoidance mindset.

Second, there were notable demographic and purpose-related shifts in who used the concourse rest spaces. We observed a higher proportion of male commuters among those in 2022, while the number of females was relatively lower. This aligns with reports indicating that women overall reduced their out-of-home travel more than men during the pandemic. It is

plausible that certain user groups who used to frequent station rest areas—for example, local shoppers or caregivers on outings—have not returned in the same numbers, skewing the post-pandemic concourse population more toward core commuters. Regarding age, our study did not identify a very clear shift in the age profile of people staying in the concourse, but generally, younger adults and those with essential jobs maintained their travel routines more than older individuals or families during pandemic restrictions. This broader trend has been noted in mobility surveys and could explain why we did not see an influx of older passengers in 2022—many retirees or cautious individuals may still have been avoiding busy public spaces, whereas students and workers had largely resumed transit use.

Third, the temporal usage patterns of the concourse changed. Our analysis from Chapter 2 (Himeji Station Front Plaza North) showed that weekend and leisure use was more impacted by COVID-19 than weekday commuter traffic. A similar pattern appears in the Osaka Monorail data: the relationship between passenger volume and the number of people remaining became steeper after COVID-19, indicating that during typically off-peak times (mid-day or weekends), far fewer people lingered in the concourse than before. Practically, the concourse is now busiest during peak commuter hours, with less casual “loitering” or discretionary use at other times. This aligns with the simulation results by Lee and Marinov, which noted that about 80% of passengers in a COVID-19 scenario moved directly through the station with only brief pauses. Our findings suggest that in the post-pandemic era, station concourses function more as transit points during off-peak hours, with much of the social or incidental use decreasing when crowds are sparse.

Finally, certain patterns of social distancing and their design implications are clear from the case study. We found that passengers mostly continued to use the same main routes in both years, but we also noted a slight increase in the use of alternative paths when the concourse temporarily became crowded. This shows a level of informal crowd-avoidance: when people encountered groups of others—for example, during a surge of alighting passengers—some chose different routes or waited briefly to keep personal space. The seating areas in the concourse remained spots for those needing a rest or to make a phone call, but these areas were less crowded than before, reflecting a decreased tolerance for close proximity while sitting. These behavioral changes highlight that future concourse design must assume users will want more space per person, especially in seating or waiting areas, than previously.

Literature supports this approach: design guidelines stress the importance of flexible seating, clear one-way flow systems, and touchless infrastructure to meet safety preferences.

For example, wider queuing lanes or sensor-based ticket gates can prevent bottlenecks and minimize physical contact, as recent research on “frictionless” station design suggests.

Overall, our findings reinforce that flexibility, openness, and low-contact features are vital in post-pandemic concourse spaces. Measures like clearly marked pedestrian paths, distributed seating that avoids clustering, and reducing shared-touch surfaces align with the new norms of distancing and quick movement. This case study also emphasizes the need to build resilience and adaptability into transit environments. Stations should be prepared not only for fluctuating volumes but also for shifts in user behavior. Our observations echo urban planning calls for more pandemic-resilient and inclusive designs in public transportation hubs. By addressing the safety and comfort of cautious travelers, station concourses can stay functional and welcoming both during normal times and in crises.

3.7 Conclusion

To clarify the impacts of the COVID-19 pandemic on passenger behaviors in rest spaces of railway station concourses, we conducted a comparative study of passenger behaviors at Osaka Monorail station concourses in 2008 (pre-pandemic) and 2022 (post-pandemic). We examine the influences of the COVID-19 pandemic on changes in passenger numbers and stays, characteristics of stay behaviors, passenger flows, and facility utilization. Based on the results, we can draw the following conclusions:

First, although the direct impact of the COVID-19 pandemic on changes in the number of stays in the concourse cannot be observed, passenger numbers more clearly influenced the number of stays in the concourse after the COVID-19 pandemic.

Second, passengers in concourses tend to spend less time in rest spaces after the COVID-19 pandemic.

Third, the COVID-19 pandemic results in a decline in the number of temporary facility users, especially boarders, which may be related to the shorter stay times after the pandemic.

This study explores how passengers' behavioral characteristics in Osaka Monorail station public spaces have changed after the COVID-19 pandemic by comparing pre- and post-pandemic data. Railway stations in Japan are common public spaces for examining the impact of COVID-19 on people's behaviors and facility use. Thus, this research offers a solid perspective for behavioral studies in public spaces, taking into account the effects of the pandemic.

This study had two limitations. First, most results are based on a single-day survey at each station and may be affected by random factors. The previous study was done in 2008, with

data collected every two hours at each station. To maintain consistency, we carried out the secondary survey in 2022, using the same subjects and conditions as in 2008, which imposed strict limitations on the subjects and survey timing. Second, as our findings indicate, over the long period between 2008 and 2022, there were changes in the arrangement and facilities in the concourses, as well as in passengers' traveling and behavioral habits. As a result, our comparative study conclusions can only be partially validated.

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CHAPTER 4 STUDY ON BEHAVIOR

CHANGES OF PEOPLE STAYING IN THE STATION FRONT PLAZA

4.1 Introduction

4.1.1 Social Background

The COVID-19 pandemic has continued worldwide since 2020. Due to its high infectivity and pathogenicity, most countries implemented various measures and policies to prevent infection in crowded places. These measures caused notable shifts in travel habits: long-distance commuting via public transit decreased sharply, while short-distance local travel increased. Studies on pedestrian behavior found that walking speeds mostly stayed the same, but people kept larger distances from each other compared to pre-pandemic norms. The pandemic also resulted in declines in certain businesses—for example, attendance at cafes, fast-food restaurants, and shopping malls dropped significantly during the outbreak. Even as restrictions eased in 2022 to support economic recovery while protecting public health, many of these behavioral changes have remained. This suggests a lasting awareness of infection risk that continues to influence how people engage in activities in public spaces.

Indirect effects of COVID-19 on railway stations include changes in passenger behavior—such as how travelers spread out, select routes, maintain social distancing, use facilities, and spend time at the station. Public parks and plazas, especially those located in front of major transportation hubs like railway stations, have traditionally served as key communal spaces for socializing, relaxing, and various activities. These areas have experienced notable shifts in usage patterns due to pandemic restrictions and changes in public behavior. Understanding these changes is essential for urban planners, architects, and policymakers as they modify such spaces to better meet public needs in the post-pandemic period.

Importantly, our previous studies confirm that these observed changes were caused by the pandemic itself rather than unrelated changes in the physical environment. This finding shows that when the spatial setting stays the same, behavioral shifts can be directly linked to COVID-19. Using the same approach, the present study compares Himeji Station Front Plaza North in 2017 and 2022, during which the plaza's physical layout remained unchanged, allowing the impact of COVID-19 to be confidently isolated.

4.1.2 Related Works

Since the COVID-19 pandemic began, many studies have looked at its effect on public space use, especially in transportation hubs. Researchers compared how people used public spaces before and during COVID-19 in cities around the world through big data analysis and field surveys, consistently showing notable changes in where and how people spend time outdoors.

1) Impact of COVID-19 on Public Space Use

The onset of the pandemic caused significant changes in how people used public space. Researchers observed a sharp decline in station passenger numbers and more short-term stays, along with more noticeable social distancing practices in station areas. However, studies on urban parks in Japan and other countries showed both an increase in daily visitors and a shift toward more local, short-distance use of these spaces. Also, the availability of many “third places” (such as cafés and community centers) dropped sharply during the pandemic, reducing indoor socialization opportunities and affecting community well-being. Even after official restrictions ended in 2022 and commercial activities started to rebound, many of these behavioral changes continued: people kept physical distance and avoided high-density crowds, showing long-term adaptations to pandemic conditions.

2) Changes in Behavioral Patterns

Besides the use of specific public spaces, the pandemic fundamentally changed daily routines and mobility patterns. During lockdowns, many workplaces and schools moved to remote operations, greatly reducing daily commuting and campus attendance. At the same time, urban populations experienced spatial redistribution: some residents moved from dense city centers to suburban areas, leading to more localized activity and a sharp decline in long-distance commuting. These changes in living and working arrangements reflected a broad adaptation to pandemic conditions and resulted in new travel and lifestyle preferences.

3) Long-term Effects and Adaptations

Even after the immediate crisis eased, many behavior changes proved to be lasting. People stayed cautious in their daily activities, continuing practices like social distancing and avoiding crowded events due to ongoing health concerns. Surveys of office workers, for example, show a continued preference for remote or flexible work instead of returning fully to daily office commutes, highlighting a permanent shift in work-life patterns and mobility habits. These long-term changes indicate that the COVID-19 pandemic has had a lasting impact on social behaviors and how shared spaces are used.

4) Innovation of Analytical Tools

To analyze these changes in public space use, researchers have employed various methods. Mobile spatial statistics and behavioral elasticity diagrams have tracked fluctuations in visitor numbers and age-specific responses over time. At a more detailed level, observational surveys in public squares and station atriums confirmed altered density and distancing behaviors, with visitors intentionally maintaining more space between each other. Together, these methods show that large-scale mobility data and direct field observations each provide valuable but different insights, and combining them offers a more complete understanding of pandemic-related changes – although each also has limitations.

Compared to extensively studied outdoor parks and downtown districts, research on railway station environments remains relatively limited. Our previous studies showed significant declines in shop usage within JR-West station concourses and shorter dwell times in Osaka Monorail rest areas after the pandemic, even though the station layouts remained unchanged. These findings confirmed that the effects of COVID-19 went beyond just a drop in passenger numbers, fundamentally affecting behavior within transit spaces. Building on these insights, the current study focuses on an open-air station front plaza—a type of public space that combines transit flows with community use but has been less examined in the literature. In this study, we integrate mobile location data with detailed field observations and divide the plaza into 13 spatial units. This approach advances previous methods and offers detailed insights into pandemic-related behavioral changes in an outdoor, transit-adjacent public space. Ultimately, the results provide new perspectives to guide the design of more resilient and adaptable public spaces in the post-pandemic era.

4.2 Method of study

4.2.1 Study area

The study focuses on Himeji Station Front Plaza North, a major transportation hub located in the city center of Himeji, Hyogo Prefecture, Japan. The plaza consists of two distinct areas: the Lawn Area and the Castle Garden, which together offer a variety of environments for both residents and travelers to relax and participate in various activities. The plaza is also surrounded by busy commercial districts, the station building, shopping streets, main roads, and hotels. Based on our field observations, the roads, transportation facilities, and businesses remained unchanged before and after the COVID-19 pandemic. This allowed us to analyze behavioral changes in the station front plaza caused solely by COVID-19 outbreaks.

To determine whether spatial preference changes were pandemic-induced, we divided the plaza into 13 distinct sub-areas based on their spatial characteristics and the high-density clusters identified in our observation results. This enabled us to systematically examine how both spatial features and the pandemic influenced crowd distribution (Figure 4-2, 4-3).

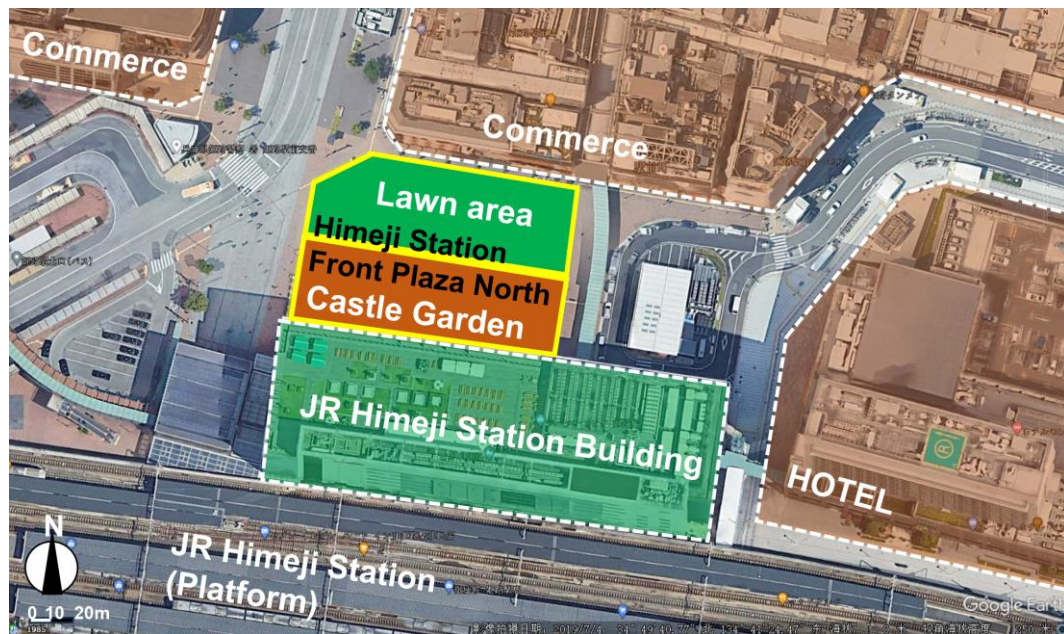


Figure 4-1 Location of Himeji Station Front Plaza North and surroundings

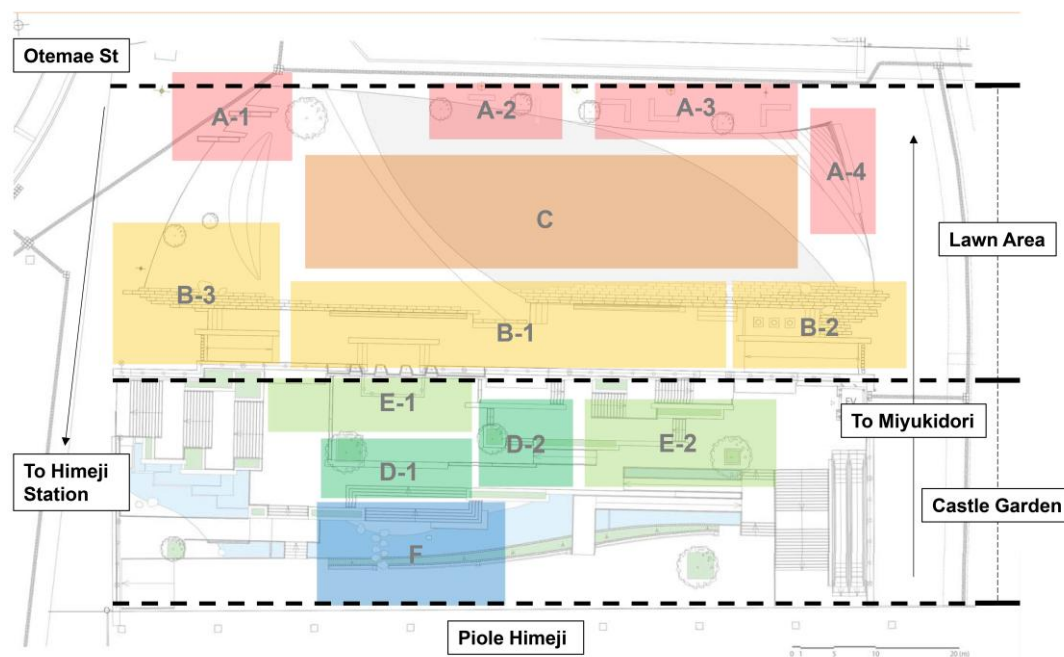


Figure 4-2 Location of Himeji Station Front Plaza North and surroundings

4.2.2 Data collection and analytical tools

A previous study was conducted on November 3, 2017 (weekend), and November 7, 2017 (weekday), to observe the behaviors of people staying at Himeji Station Front Plaza North. Using four observers, we carried out field observations and collected data on the spatial distribution, on-site behaviors, and basic information of people (gender, age) in the plaza. A follow-up investigation using the same methodology was carried out on November 5, 2022 (weekend), and November 8, 2022 (weekday), on a comparable date within the same month and under similar weather conditions. We analyzed the field data collected on people in the plaza using QGIS 3.30.3 to generate heatmaps visualizing crowd spatial distribution. Field observations and data collection took place from 10:00 AM to 5:00 PM daily.

To supplement field observations conducted in 2017 and 2022, continuous stay data from 2018 to 2023 were collected using the KDDI Location Analyzer. This system provided time-

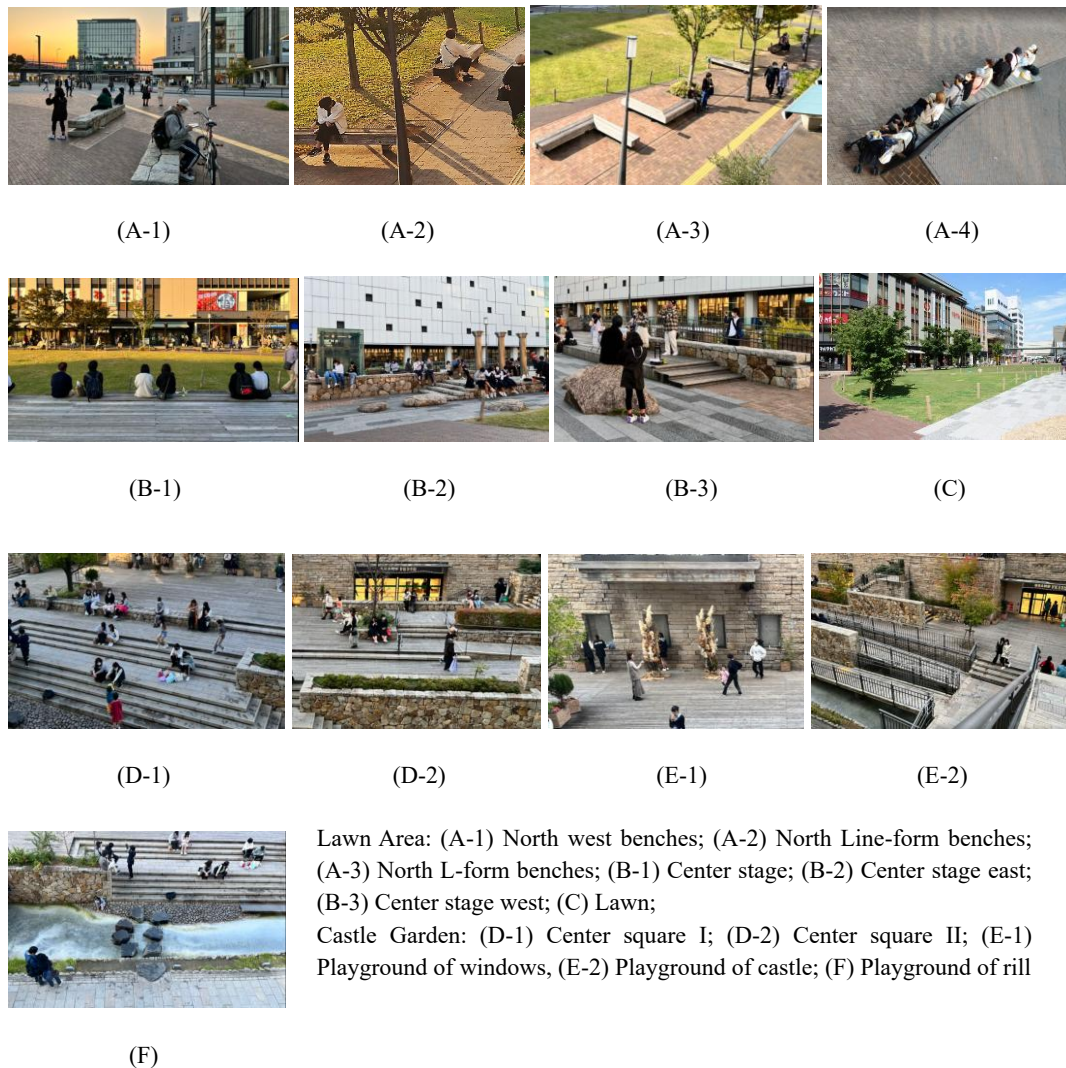


Figure 4-3 Sub-areas in Himeji Station Front Plaza North, images of spaces and behaviors

series data on the number of people staying in the plaza, allowing for a detailed analysis of how the COVID-19 pandemic impacted plaza usage before, during, and after the outbreak. It can identify individuals who stay for more than 15 minutes by filtering mobile GPS positioning data within a customized space and time range, and then linking it with identity information to obtain stay data. KDDI system data collection also occurred daily from 10:00 AM to 5:00 PM

4.3 Impact of the COVID-19 pandemic on number of stays in Himeji Station Front Plaza North

As the background, through Figure 4-4, we realize that the passenger numbers of Himeji Station were stable before 2020 and dropped dramatically in 2020 due to the outbreak of COVID-19. The number rose gently from 2021 but is still lower than before COVID-19. It is clear that COVID-19 has a significant impact on the passenger numbers at Himeji Station.

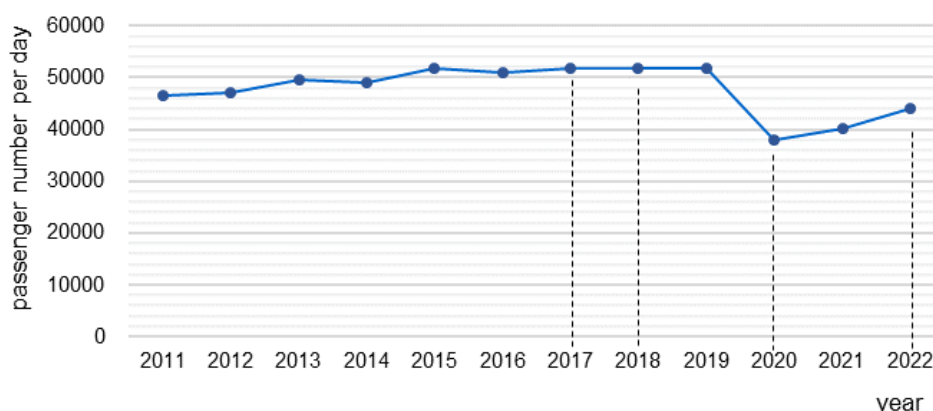


Figure 4-4 Change in average daily passenger number of Himeji Station

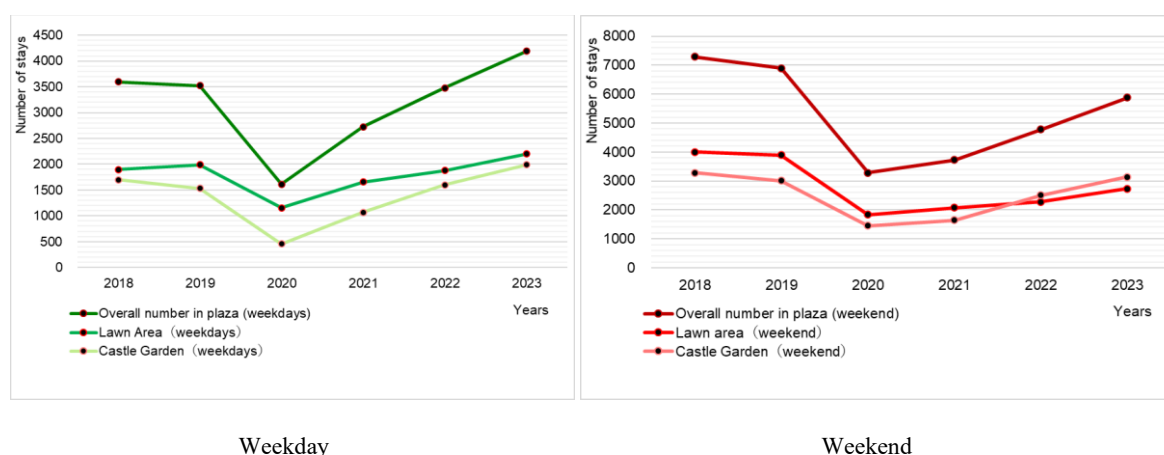


Figure 4-5 Changes in number of stays from 2018 to 2023

Table 4-1 Number of stays in two years in two plazas

Days	Plazas	Years	Overall	Gender		Ages				Behaviors				
				Males	Females	Child and student	Youth	Middle ages	Aged	Resting	Talking	Phone	Eating	Playing
Weekdays	Lawn area	2017	352	183	169	56	130	95	71	61	126	68	11	24
		2022	501 (†)	288 (†)	213 (†)	72 (†)	232 (†)	127 (†)	70	138 (†)	131	87 (†)	26 (†)	31
	Castle garden	2017	85	29	56	43	32	7	3	4	23	16	8	2
		2022	242 (†)	105 (†)	144 (†)	59	149 (†)	30 (†)	4	21 (†)	53 (†)	19	13	26 (†)
	Overall	2017	437	203	234	99	166	124	48	65	149	84	19	209
		2022	750 (†)	393 (†)	357 (†)	132 (†)	385 (†)	159 (†)	74 (†)	159 (†)	184 (†)	106 (†)	39 (†)	360 (†)
Weekend	Lawn area	2017	2864	1013	1851	844	970	862	188	174	495	93	6	88
		2022	1761 (↓)	715 (↓)	1046 (↓)	301 (↓)	615 (↓)	692 (↓)	153	206 (†)	480	134 (†)	77 (†)	155 (†)
	Castle garden	2017	592	181	411	386	172	34	2	18	262	31	9	121
		2022	1281 (†)	334 (†)	947 (†)	566 (†)	399 (†)	279 (†)	37 (†)	48 (†)	353 (†)	76 (†)	96 (†)	205 (†)
	Overall	2017	3456	1194	2262	1230	1142	896	188	192	757	124	15	209
		2022	3042 (↓)	1049 (↓)	1993 (↓)	867 (↓)	1014 (↓)	971 (†)	190	254 (†)	833 (†)	210 (†)	173 (†)	360 (†)

Figure 4-5 shows the changes in the number of stays at Himeji Station Front Plaza from 2018 to 2023, based on data from the KDDI location analyzer. First, we can observe a dramatic drop in the number of stays at Himeji Station Plaza in 2020, along with a decline in passenger numbers. Second, starting in 2021, both on weekdays and weekends, there was an increase in the number of stays at Himeji Station Plaza. Third, the growth rate of stays on weekdays exceeds that on weekends.

Table 4-1 shows a comparison of the number of stays between 2017 and 2022 across different plazas, genders, ages, and behaviors. First, we observe that on weekdays, the total number of stays as well as stays in both the Lawn area and Castle Garden in 2022 are higher than in 2017. However, on the weekend of 2022, the total number of stays and stays in the Lawn area for both males and females, as well as people of different ages, was all lower than in 2017. Conversely, the total number of stays and the number of stays for each age group in Castle Garden during the 2022 weekend are higher than in 2017. Secondly, from a behavioral perspective, the total number of stays on both weekdays and weekends in 2022 for all five categories exceeds that of 2017. Additionally, the number of stays in Castle Garden across all behavioral categories increased significantly during the 2022 weekend.

From Figure 4-6, we can see that the proportion of males on weekdays increased both in the Lawn Area and the Castle Garden in 2022 compared to 2017. On weekends, the proportion of males increased in the Lawn Area but decreased in the Castle Garden. When discussing the proportion by different ages, we can see from Figure 4-7 that on weekdays, only the proportion of youth has increased overall and in both Lawn Area and Castle Garden. The proportion of children and students in Castle Garden on weekdays dropped dramatically from around 50% to less than 30%. The proportion of youth increased in both areas. On weekends, overall, the proportions of youth stay almost the same between the two years, and

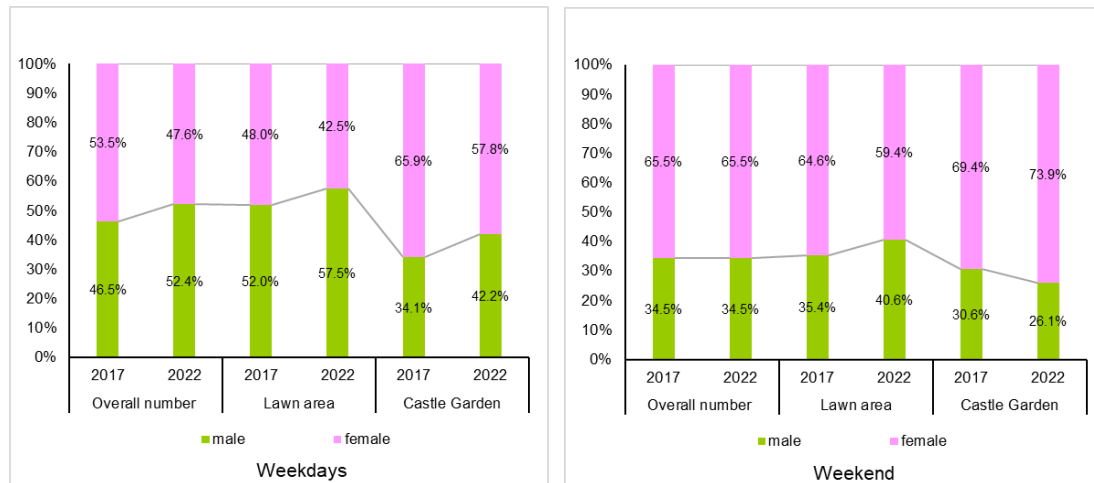


Figure 4-6 Proportion of males and females in two years

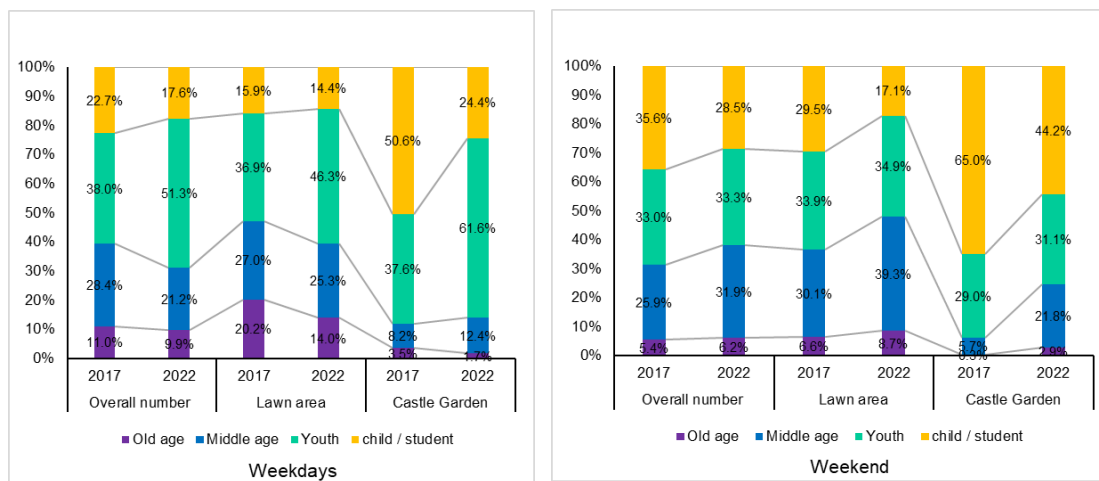


Figure 4-7 Proportion of four age groups in two years

the proportion of children or students increased while the proportion of the Middle Ages decreased. The same trend was seen in the Lawn Area. In Castle Garden, the proportion of children or students dramatically decreased from around 65% to 45%, and the proportion of Middle Ages increased from around 5% to 20%.

We understand that the railway station front plaza, located next to the station building, functions as a temporary waiting and gathering area for passengers boarding and alighting. Therefore, changes in the number of people in the station square are closely linked to fluctuations in passenger flow during the same period.

At the same time, the railway station front plaza also functions as a civic plaza for the city. In addition to rail passengers, it is utilized by residents, especially when surrounded by commercial and public facilities. Consequently, the number of people in the station plaza is

also influenced by factors such as weather conditions, holidays, special public events, and large-scale social events.

The COVID-19 pandemic, which started in early 2020 as a major public health crisis, significantly impacted railway transportation in Japan. As shown in Figure 4-4, passenger numbers at JR Himeji Station in 2020 dropped sharply compared to previous years. Although ridership gradually recovered in the following years, it stayed below pre-pandemic levels.

Additionally, using the KDDI Location Analyzer system, we gathered annual data on the number of people at Himeji Station Front Plaza, including both weekdays and weekends, with separate counts for the Lawn Area and Castle Garden. The results show that plaza occupancy trends were similarly affected by the pandemic, reflecting the decline in passenger numbers. This suggests that the pandemic had a comparable impact on both railway passenger volumes and station plaza occupancy.

4.4 Impact of the COVID-19 pandemic on distribution of stays in Himeji Station Front Plaza North

Through the observation, we also identify significant differences in the distribution and composition of stays before and after COVID-19. We collected data on the distribution of staying people by gender, age, and behavior to conduct a comparative study on stays at Himeji Station Plaza. We use heatmaps to illustrate the differences in stay distribution between the two years.

4.4.1 Comparison of overall distribution of stays

As shown in Figure 4-8, several key points become clear when comparing the overall crowd distribution in the plaza on weekdays and weekends between the two years. First, the number of people in the plaza on weekdays was consistently lower than on weekends. Second, the areas with crowds expanded after the COVID-19 pandemic compared to before it. Third, before the pandemic, crowds on weekdays mainly gathered in the Lawn Area, but afterward, they appeared in both the Lawn Area and Castle Garden. On weekends, the high-density crowd areas in the Lawn Area remained mostly unchanged before and after the pandemic, while there were noticeable shifts in crowd distribution in Castle Garden.

The comparative study shows that the different spatial layout of Himeji Station Front Plaza North's outdoor areas has created clearly recognizable popular gathering spots where people often choose to stay. The COVID-19 pandemic not only changed the total number of visitors to the plaza but also significantly shifted these preferred gathering spots.

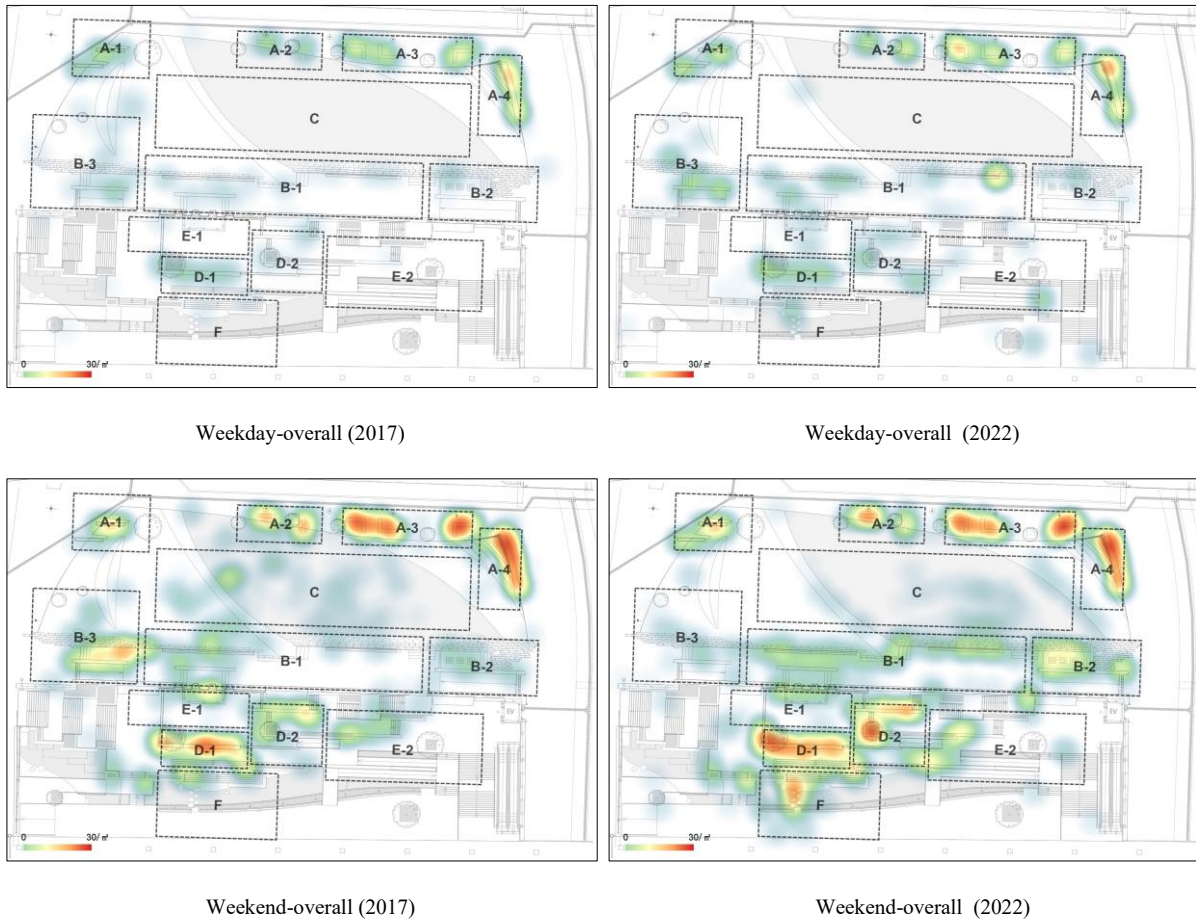


Figure 4-8 Distribution of overall stays of two years

4.4.2 Classified Comparative Study on Crowd Distribution

We divided the plaza into 13 areas based on their orientations and spatial features, depending on where people mainly gathered. There are 8 areas in the Lawn Area (A-1, A-2, A-3, B-1, B-2, B-3, C) and 5 areas in Castle Garden (D-1, D-2, E-1, E-2, F), as illustrated in Figure 4-2. Details about each area's elements, locations, orientations, and spatial characteristics are listed in Table 4-2. Additionally, the number of hours each area received direct sunlight on the survey day under clear conditions was estimated through simulation.

Table 4-3 shows a comparative heatmap analysis of crowd gathering areas at Himeji Station Front Plaza across three demographic groups (overall, male, and female) before and after the COVID-19 pandemic (i.e., on weekdays and weekends in 2017 and 2022). The results reveal several notable patterns: First, among the 13 sub-areas, A-1 to A-4 in the Lawn Area and D-1 to D-2 in the Castle Garden consistently showed the highest concentration of visitors, regardless of weekday/weekend differences or pandemic-related changes. Second, for the overall population and gender-specific groups, the distribution of crowds on weekdays remained largely the same before and after the pandemic. We used field observations to

Table 4-2 Characteristic of 11 areas in lawn area and castle garden

Plazas	Areas	Elements	Location and orientation	Spatial characteristics	Sunshine duration	
Lawn Area	A-1	North west benches	Two stone benches, clock	On the east side of the main road, the Otemae street; Along the path of the station; Facing north to the station and south to the Otemae street	Without shelter, no roof.	9
	A-2	North line-form benches	Two wood benches, trees	In the middle of the north side of Lawn Area. With one bench facing north to the coffee store and south to the lawn, and another bench facing east and west.	Under the trees, near the café. One of the benches reached into the lawn.	8.5
	A-3	North L-form benches	Three L-form wood benches, gentle slope	In the east of the north side of Lawn Area. Between the lawn and shops. Seats with four orientation	Two of the L-form benches are close together, to each other, the last one is near the gentle slope on the northeast.	8
	A-4	North east long bench	Long wood bench, low slope	on the northeast of the Lawn Area, facing to the east.	Closest to the Miyukidori pedestrian street, facing directly to the flow between pedestrian and station building. There is an entle slope behind it.	6
	B-1	Center stage	Wood benches, stage, steps	Middle of center stage, between Lawn Area and Castle Garden, facing north to the lawn.	The boundary of the center stage are taken as benches, facing to the lawn in the north.	8
	B-2	Center stage east	Stone benches, steps, low walls, playground, stone seats	The east part of center stage in lawn area, close to the entrance of station building. Mostly facing to the north.	The intersection space between center stage and flow from pedestrian. Low wall and steps are taken as seats by many people. There are several stone seats on the playground. Close to the elevator and steps to underground.	5
	B-3	Center stage west	Wood and stone benches, stage, playground, statues	The west part of center stage in lawn area, Mostly facing to the north.	Almost same as Center stage east; besides the path to the station and Otemae main street. A bigger playground.	8.5
	C	Lawn	Lawn and footpath, no seats	Center lawn area.	Grass surface with a footpath crossing from north west to the middle of center stage. People gather and mostly facing to the center stage in the south during activities.	9
	D-1	Center square I	Stone benches, steps, tree	In the center of Castle Garden, facing to the south.	High position in Castle Garden. There are also seats under a tree. Close to the rill.	1
	D-2	Center square II	Stone benches, steps, tree	Northeast to the Center square I, facing to the south.	Highest position in Castle Garden. There are also seats under a tree. Much further from the rill.	1
Castle Garden	E-1	Playground of windows	Playground with wood surface, windows with seats, steps	North to the Center square I.	A flat playground with wood surface. People play and chat on the ground or stand leaning against the ledge of four windows. Without shelter, no roof.	1.5
	E-2	Playground of castle	Low stone walls, slopes with handrails, steps	East of Castle Garden.	Consist of disabled ramps, steps and low walls with various heights, people stand leaning against the walls or sit on the walls.	1
	F	Playground of rill	Steps, playground near rill	In the south of Castle Garden, back to the station building.	A rill running from west to east, separating the Castle Garden and the station building. There are steps from the benches to the rill and stepping stones along and on water.	0

categorize visitors. Numbers increased significantly in Area B of the Lawn Area and Area D of the Castle Garden.

Third, the number of stays on weekends increased significantly after the pandemic, with crowds spread more evenly across the plaza compared to weekdays. Notably, the Castle Garden hosted a much larger share of stays after COVID-19 than before the pandemic.

We use field observation to categorize stays into four age groups to examine pandemic-induced behavioral changes: Children and students (~20 years), Youth (20-40 years), Middle-aged (40-60 years), and Seniors (60+ years). We kept the same observers for each recording session and maintained an observation distance within 10 m to ensure consistency in age

Table 4-3 Comparison of crowd distribution on weekday and weekend (overall, male, and female)

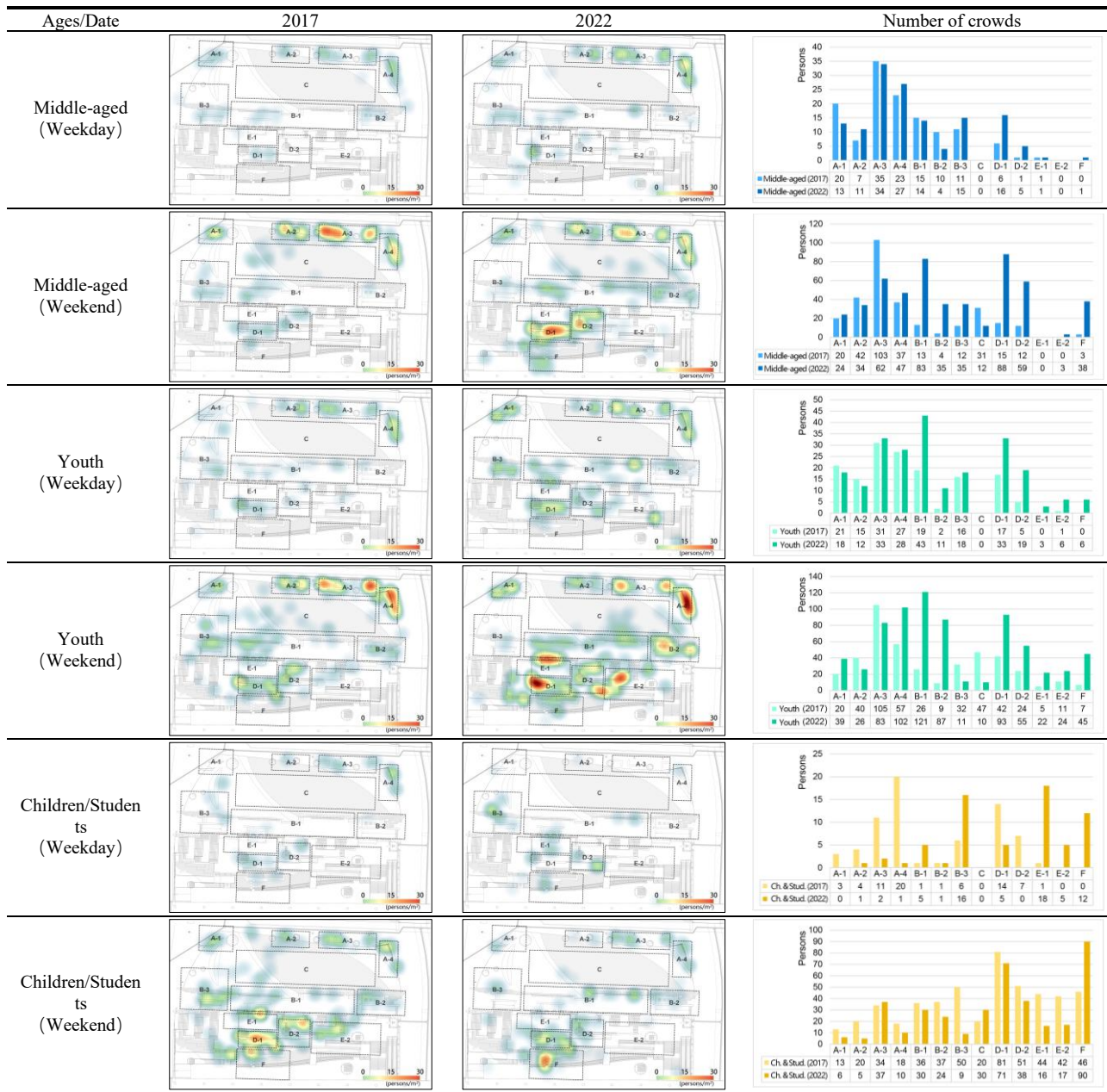
Years/Date	Overall	Male	Female
2017 (Weekday)			
Gathering areas	A-1, A-2, A-3, A-4, D-1	A-1, A-2, A-3, A-4	A-1, A-3, A-4, D-1
2022 (Weekday)			
Gathering areas	A-1, A-2, A-3, A-4, B-1, B-3, D-1	A-1, A-2, A-3, A-4, B-1, B-3, D-1, D-2	A-2, A-3, A-4, B-3, D-1
2017 (Weekend)			
Gathering areas	A-1, A-2, A-3, A-4, B-3, D-1, D-2	A-1, A-2, A-3, A-4	A-1, A-2, A-3, A-4, B-3, D-1, D-2
2022 (Weekend)			
Gathering areas	A-1, A-2, A-3, A-4, B-1, B-2, D-1, D-2, E-2, F	A-1, A-2, A-3, A-4, B-1, B-2, D-1, D-2, F	A-1, A-2, A-3, A-4, B-1, B-2, D-1, D-2, E-2, F

categorization. Since the comparative analysis showed minimal distributional changes among Seniors before and after the pandemic, this group has been omitted from Table 4-4. Key findings from our analysis include:

(1) Youth and middle-aged users showed a significant shift to the Castle Garden during both weekdays and weekends after the pandemic, with D and F continuing to be the most popular gathering spots.

(2) Children/student groups displayed distinct behavioral patterns: On weekdays, they predominantly concentrated in B-3, E, and F. On weekends, the number decreased overall, though Area F saw increased usage.

Table 4-4 Comparison of crowd distribution on weekday and weekend (Middle-aged, Youth, Children/Students)



(3) The persistence of D and F as preferred areas across multiple demographic groups suggests these areas possess inherent spatial qualities resilient to pandemic disruptions.

Based on the observation of behaviors over two years, five main categories are identified: resting, conversing, using mobile phones, eating, and playing. By studying the distribution of stays in the two plazas as shown in Figure 4-9, we can first see that the proportions of resting, conversing, and using phones were higher in the Lawn Area than in Castle Garden on both weekdays and weekends across the two years. Meanwhile, the proportions of eating and playing were higher in Castle Garden than in the Lawn Area on weekends. Second, compared

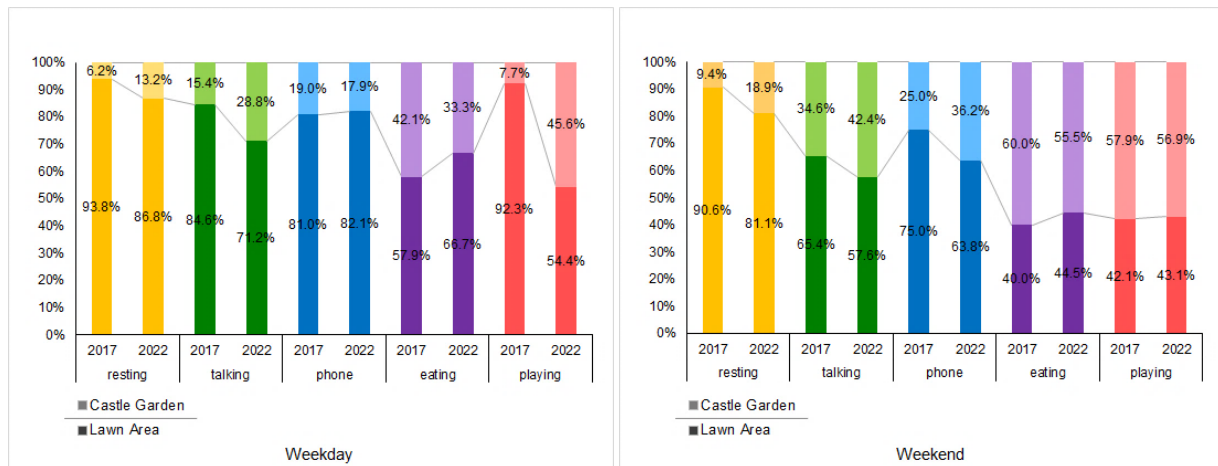


Figure 4-9 Proportion of stays in two plazas by behaviors

to 2017, in Castle Garden, the proportions of talking and playing on weekdays, and resting, talking, and using phones on weekends, were higher in 2022.

From the results above, we can observe distinct behavioral patterns in the use of the two plazas, with some behaviors showing different trends between weekdays and weekends. Additionally, Table 4-5 displays the number and distribution of these behaviors across 13 areas. In the bar chart, we used color to highlight the top three to five areas where each behavior was most frequently observed.

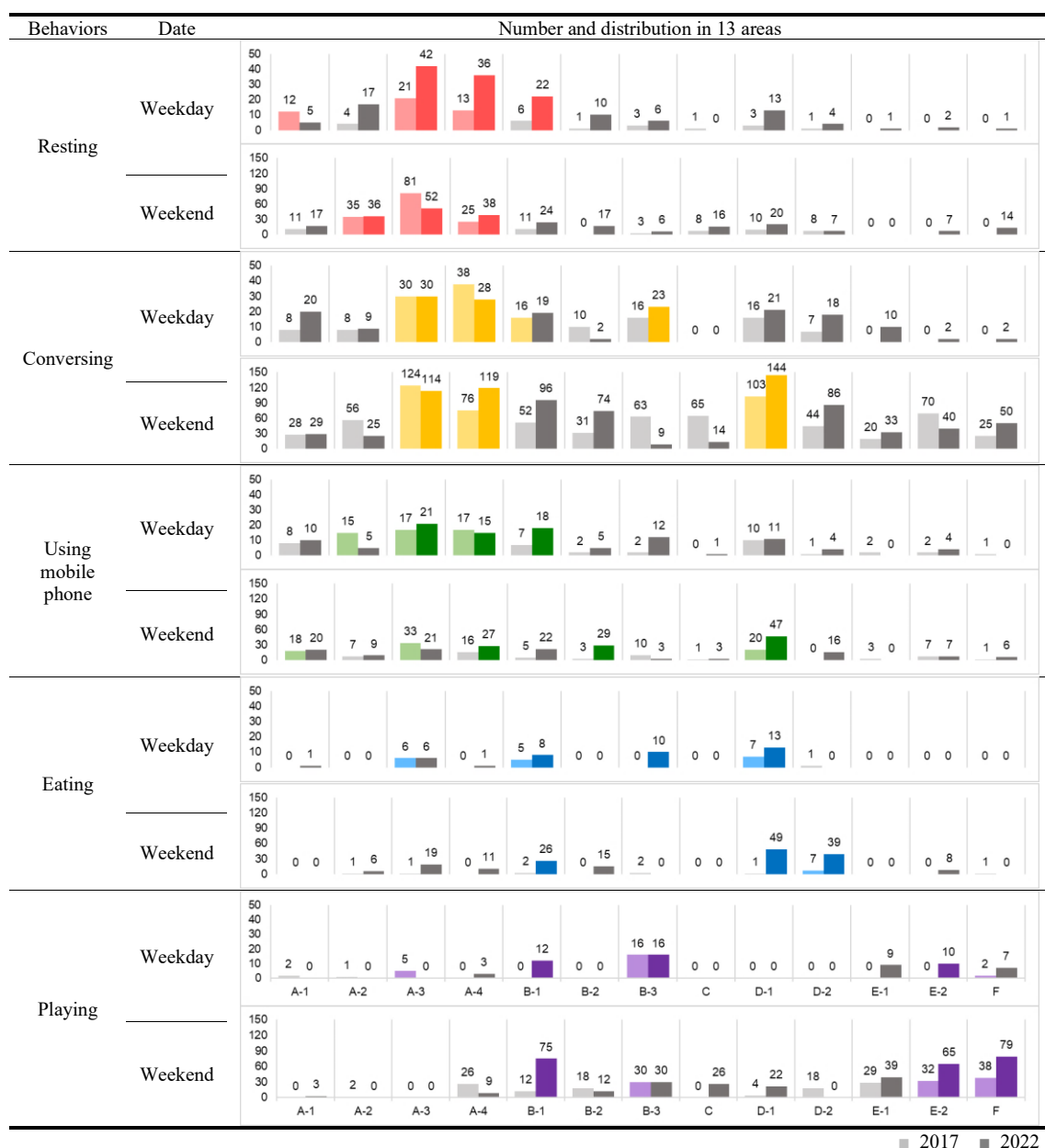
Overall, during the post-pandemic period, there has been a noticeable increase in four of the five behaviors, excluding "resting," in Castle Garden. Specifically, "conversing," "using mobile phones," and "eating" were most frequently observed in Areas B and D, while "playing" showed a significant increase in Areas E and F. This result aligns with the previously observed rise in the number of children and students in Areas E and F. The likely reasons are related to the spatial characteristics of Areas E and F, which offer more engaging environments, stronger connections to natural landscapes, and facilities such as playgrounds and water features.

4.5 Discussion

1) Impact of COVID-19 on Visitor Numbers at Himeji Station Front Plaza

A field study on the impact of COVID-19 on stay patterns at Himeji Station Front Plaza, using observations from 2017 and 2022, showed clear differences in how stay numbers changed between weekdays and weekends. Compared to 2017, 2022 experienced significant drops in several metrics: passenger numbers at Himeji Station, the total stays in the plaza on weekends, the number of male and female stays across the plaza and the Lawn Area on

Table 4-5 Comparison of crowd distribution on weekday and weekend by five types of behaviors



weekends, and the counts of children, students, youth, and middle-aged individuals in both the plaza and the Lawn Area on weekends.

Conversely, in 2022, increases were noted in the total number of stays at both Himeji Station Front Plaza and Castle Garden on weekdays. There was also a rise in the number of male, female, child, student, youth, middle-aged, and elderly visitors staying in these areas on both weekdays and weekends. Additionally, an analysis of stay numbers from 2018 to 2023 using the KDDI Location Analyzer showed consistent trends in visitor counts on weekdays and weekends. The results also indicated similar patterns between passenger numbers at Himeji Station and visitor numbers at the Himeji Station Front Plaza. To better understand COVID-19's impact on visitor trends in the plazas, a correlation analysis was performed using

continuous data from 2018 to 2023, comparing passenger counts at Himeji Station, visitors to the Himeji Station Building, and stays in the Himeji Station Front Plaza on both weekdays and weekends.

The COVID-19 pandemic brought significant changes to patterns of human mobility and public space usage, and Himeji Station Front Plaza was no exception. A field study examining how COVID-19 affected the presence of people in Himeji Station Front Plaza, based on observations from 2017 and 2022, revealed clear differences in the number of stays between weekdays and weekends. As detailed in Chapter 4.3, passenger numbers using Himeji Station dropped sharply in 2020 after the pandemic began. This decline in transit use was closely followed by a decrease in the number of people staying at the station plaza, confirming its dual role as both a transit waiting area and a civic space.

Additionally, an analysis of continuous changes in stay numbers from 2018 to 2023, using the KDDI Location Analyzer, revealed consistent trends in the number of stays on both weekdays and weekends. The findings also showed similar patterns between the changes in passenger numbers at Himeji Station and the number of stays at Himeji Station Front Plaza. However, unlike the field observations, which indicated a significant post-pandemic increase in weekend stays, the results from KDDI showed a decrease on weekends. Since the KDDI statistics only include individuals with a minimum dwell time of 15 minutes, it can be inferred that post-pandemic visitors tend to stay for shorter durations. This pattern suggests a lasting behavioral shift in how people engage with urban public spaces, possibly influenced by broader changes in commuting habits, telework adoption, and lingering public health concerns.

2) Impact of COVID-19 on distribution of stays in Himeji Station Front Plaza

Based on a two-year comparative study of stays at Himeji Station Front Plaza, we can see both quantitative and spatial effects of COVID-19 on how the plaza was used. The pandemic not only lowered the total number of visitors but also shifted where people chose to stay within the space. These spatial changes seem to be closely tied to behavioral and psychological responses to the pandemic, especially concerns about health, comfort, and perceived safety in public areas.

Firstly, regarding overall distribution, the basic pattern of use remained recognizable across the two years. Before COVID-19, most visitors focused on the Lawn Area, especially in sub-areas A-1 to A-4, which were popular because they were central and offered good sun exposure. By 2022, on both weekdays and weekends, the Lawn Area continued to draw many visitors. However, an important shift occurred after the pandemic: more people started to

choose the Castle Garden, especially Areas D and F. The Castle Garden offers more greenery, more open space, and a clearer separation between groups. These features likely made it feel less risky during and after the pandemic, creating a sense of calm, controlled distance, and less exposure to others. In this way, users' spatial preferences cannot be seen only as a matter of convenience or centrality; they should be understood as a post-pandemic preference for semi-open environments that balance accessibility with psychological safety.

Secondly, when dividing the plaza into several areas, we observed notable differences in how specific zones were chosen before and after the pandemic. In the pre-pandemic condition, Areas A, B, and D were among the most frequently used locations. After the pandemic, these areas remained important, but their usage patterns changed. On weekdays, more visitors were seen in Areas B and D. On weekends, visitors gradually shifted from Area B-1 toward Areas B-2 and B-3. Simultaneously, after the pandemic, there was a significant increase in stays in Castle Garden sub-areas like D and F, which have more greenery and less clustering. This suggests that weekend spatial distribution was more impacted than weekday distribution: people on weekends seemed more selective about where they stayed, choosing spaces that offered comfort, distance from strangers, and a chance to pause without feeling crowded.

Thirdly, analyzing the distribution patterns across different demographic groups reveals varied space usage. In 2017, youth, middle-aged, and elderly visitors mainly stayed in Area A (within the Lawn Area). By 2022, after COVID-19, more visitors from these age groups were observed in Areas B and D, especially in zones like D and F within Castle Garden. Children and students, meanwhile, more often gathered in areas such as E-1, E-2, and F, which tend to have softer or more playful features like trees, water features, casual seating, and informal edges. These areas support low-pressure activities such as sitting, talking, snacking, using mobile phones, or socializing loosely without dense crowds. After the pandemic, there was a clear increase in behaviors like talking, eating, and using mobile phones in Castle Garden, indicating that people were not just passing through but actively spending relaxed, casual time there. In other words, Castle Garden started to serve as a preferred "safe social zone," where people could stay longer in smaller groups while maintaining comfortable personal distances.

Lastly, regarding gender, the spatial distribution of male and female visitors generally followed the overall distribution trends in both years. Both men and women shifted their stays toward the Castle Garden and peripheral areas after the pandemic, rather than remaining concentrated only in the most central parts of the Lawn Area. This indicates that the change in spatial preference was broadly shared and was not limited to one gender. However, what

changed more clearly than gender composition was how people used the space: post-pandemic stays were more often associated with informal, low-contact activities carried out in semi-open, greener, and visually sheltered zones, rather than conventional waiting in the most central, exposed areas.

In summary, while the basic layout of spatial use at Himeji Station Front Plaza remained after COVID-19, the pandemic clearly affected which parts of the plaza were chosen, why they were selected, and how they were used. The shift from the Lawn Area's most central sub-areas (A-1 to A-4) toward the Castle Garden sub-areas (especially D and F) shows an adjustment to spaces that feel healthier, calmer, and more controllable. This change was especially noticeable on weekends, when the plaza functions less as a transit waiting area and more as a place for leisure and informal gathering. Therefore, although weekday patterns still mostly reflect transit needs, weekend spatial patterns were more significantly reorganized by the pandemic. These findings suggest that COVID-19 did not just decrease overall plaza use; it actively changed how people viewed comfort, proximity to others, and suitable places to stay within the same layout.

3) Relationship between spaces and behaviors

Based on the study of space categories and behavioral characteristics in plazas, we identified the five most common behaviors observed and the specific behaviors most frequently associated with each area. Resting, talking, and using mobile phones were the three most commonly observed behaviors in both years. Additionally, behavioral differences were noted among people in the two plazas.

Firstly, in the Lawn Area, across both years and on both weekdays and weekends, resting, talking, and using mobile phones remained the most common behaviors. Compared to 2017, there was a significant increase in the number of people resting on weekdays in 2022. Conversely, on weekends in 2022, the number of people resting significantly decreased, while the number of people playing increased substantially.

Secondly, in the Castle Garden, behaviors were fairly evenly distributed on weekdays, with talking being the most common activity. On weekends, talking still dominated, but there was a noticeable rise in eating and playing.

Finally, the occurrence of specific behaviors varied depending on where people stayed in the plazas. The results indicate that Areas A3 and A4, which are closer to the pedestrian street, attracted more people. In Area B, talking was most frequently observed in B1, while playing was mainly seen in B2 and B3, which have larger open spaces. Similarly, Areas C, E, and F, which have limited or no seating, experienced more playing activities. In contrast, Area

D, which has plenty of seating, saw the highest frequency of talking, eating, and using mobile phones.

From these observations, we can conclude that areas near high pedestrian traffic attract more visitors, while areas with plenty of seating encourage activities like resting, talking, and using mobile phones.

4.6 Conclusion

This chapter examined the impact of the COVID-19 pandemic on stay behaviors at the JR Himeji Station Front Plaza North. By combining two types of data — detailed, location-based field observations from 2017 (pre-pandemic) and 2022 (post-pandemic), and continuous stay data from the KDDI Location Analyzer spanning 2018 to 2023 — we analyzed how the pandemic affected (1) the total number of people remaining in the plaza, (2) how their stays were distributed across different parts of the plaza, and (3) the behavioral traits of those who stayed.

First, regarding the number of stays, the pandemic caused a sharp decline in plaza usage. The number of people staying in the plaza dropped significantly in 2020, coinciding with the decrease in railway passenger numbers during the initial COVID-19 outbreak. Although both ridership and plaza usage gradually recovered in the following years, they did not reach pre-pandemic levels. This shows that the pandemic resulted not only in a temporary shock but also in a structural change in how public space is used. Likely factors include the increase in telework, a decrease in long-distance commuting, and a heightened caution about spending unnecessary time in public, busy locations. In other words, the station-front plaza, which was once consistently active, experienced a clear decrease in overall use and has not yet fully regained its pre-pandemic activity level.

Second, regarding the spatial distribution within the plaza, COVID-19 did not simply reduce activity uniformly; it changed where people chose to stay. Before the pandemic, many visitors gathered in the Lawn Area, especially in the central and highly visible sub-areas (A-1 to A-4), which offered direct access, openness, and good sunlight. After the pandemic, however, a clear redistribution of stays occurred. More people moved toward the Castle Garden areas such as D and F, which provide more greenery, flexible seating and gathering options, and greater separation between groups. These sub-areas seemed to offer a stronger sense of psychological comfort — a calmer atmosphere, perceived safety, and the ability to maintain distance from strangers. This shift was especially noticeable during weekends, when the plaza functions less as a transit space and more as a leisure or meeting area. We also

observed that children and students were more frequently seen in sub-areas like E-1, E-2, and F after the pandemic, indicating that these greener, semi-open, lower-density areas became preferred spots for informal gatherings, light play, or casual rest.

Third, the observed behavior patterns within the plaza shifted in character. After COVID-19, activities such as talking, eating, and using mobile phones more often occurred in greener, visually comfortable, and less crowded parts of the plaza instead of its most central, exposed, high-traffic areas. This shows that the plaza was not only used as a passageway but also as a semi-social, semi-private space where people could take a break, chat, rest, or handle personal tasks on their phones without feeling surrounded by a dense crowd. These findings indicate a move away from dense, centralized gathering toward more spread-out, short visits with lower density.

Taken together, these results suggest that the pandemic's impact on the plaza was twofold: it reduced total usage, and it reorganized spatial preference. Users increasingly relocated to greener, more open sub-areas that provided both environmental amenity and perceived safety. The Castle Garden, in particular, emerged as a post-pandemic "safe social zone," attracting youth and other users who sought spaces that felt comfortable for talking, eating, and phone use without prolonged close contact with others. This pattern reflects a broader redefinition of acceptable public proximity and shared presence in urban station spaces after COVID-19.

These behavioral shifts have direct implications for future station plaza design and management. The evidence indicates that enhancing greenery, visual comfort, and perceived safety is not merely an aesthetic choice but a functional necessity for maintaining plaza vitality under public health stress. Practically, this highlights two main design and operational priorities: (1) reinforcing green, semi-open areas that offer psychological reassurance and space to spread out, and (2) decentralizing basic amenities (seating, shade, light-touch rest functions) across multiple sub-areas instead of concentrating them in a single highly exposed central zone. Providing smaller, distributed spots for short breaks—rather than one dense gathering point—would better support post-pandemic usage patterns, where people prefer brief, casual visits in lower-density settings. This approach also aligns with resilience goals: a plaza that can adapt to dispersed, short-term use is better able to remain functional and welcoming during future health crises.

This study has two main limitations. First, although we used continuous stay data from 2018 to 2023, our core observations were only conducted in two target years, 2017 and 2022. A longer series of on-site observations, including intermediate years during the peak of the pandemic, would provide a clearer picture of how behaviors changed during different phases:

pre-outbreak, peak restrictions, phased reopening, and post-restriction stabilization. Second, our analysis is limited to a single site — JR Himeji Station Front Plaza North. While this plaza is a typical example of a major railway station forecourt in a regional city, its layout, greenery, and relationship to commercial facilities are very specific. Therefore, caution is needed when applying these findings to other stations, such as busy metropolitan terminals or smaller local stations with less extensive forecourts.

Future research should therefore explore two main areas. First, conducting comparative studies across multiple station plazas in various urban and regional settings would help determine whether the post-pandemic shift toward greener, semi-open, and psychologically “safer-feeling” spaces is common or dependent on context. Second, developing more detailed behavioral classifications — for example, differentiating between “waiting for someone,” “resting alone,” “small-group socializing,” “eating,” and “using mobile phones” — would enable a more nuanced understanding of how different user needs correspond to various spatial sub-areas. Connecting these refined behavioral categories to demographic factors (such as age group, gender, and purpose of visit) and micro-spatial features (like shade, seating style, visual enclosure, presence of plants or water features) would further elucidate how public health events alter the everyday use of shared urban spaces.

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CHAPTER 5 DISCUSSION

5.1 Key Findings

Across all three case studies, the COVID-19 pandemic caused clear shifts in how people used West Japan Railways' station spaces, with consistent spatial, demographic, and temporal patterns emerging. Generally, passenger presence and stationary activities declined, and the remaining users tended to spend less time loitering in transit areas. For example, at Himeji Station Plaza, our observations show that stay behaviors changed significantly after the pandemic. On both weekdays and weekends, areas A-3 and A-4 continued to host resting and talking activities, but overall occupancy increased in new locations. In 2022, we saw more people in Area B of the Lawn Area and in the Castle Garden (Area D) compared to 2017. Notably, resting, talking, and mobile-phone use increased in 2022, while children and students—who prior to the pandemic favored the open Lawn—shifted into the Castle Garden play areas. Children's and students' presence in the Lawn Area dropped sharply on weekdays in 2022, with a corresponding rise in the Castle Garden. Middle-aged and elderly visitors continued to prefer the lawn seating, whereas teens and middle-aged adults increasingly occupied the sheltered plaza edges. These shifts suggest that younger users looked for more secluded or ventilated spots, avoiding the central benches. Overall, all five activity categories (resting, talking, phone use, eating, playing) appeared in both years, but short-term, individual activities (phone use, talking) became relatively more common after the pandemic, while long-group leisure activities (eating and playing) became more spatially confined to areas near the canal fountain and playground.

The Osaka Monorail concourse study similarly found that the pandemic intensified existing usage patterns. Compared to the 2008 baseline, patrons in 2022 were much less likely to linger in concourse rest areas, especially during boarding periods. The study by Mao and Yokota (2025) confirms our data: after COVID-19, commuters were “more inclined to minimize their stay time in rest spaces,” and the number of people using vending machines, newsstands, and seating areas decreased significantly. In concrete terms, our video surveys at fourteen Osaka Monorail stations showed fewer non-boarding passengers using the concourse lounges, and even the art corner spaces experienced shorter dwell times. Peak-hour users (morning/evening) tended to pass through without stopping for brief rests or browsing, so only a small core of non-boarding riders used the bench areas. As expected from prior transit research, ridership on the monorail overall dropped in 2020–21, but behaviors among those

still riding also changed: group sizes at resting areas shrank and stay durations decreased. For example, we observed that on weekdays, talking and phone use mostly occurred in areas A-3/A-4, but after 2020 these were mainly short chats or quick calls rather than lingering conversations. On weekends, mobile-phone use shifted toward sheltered concourse corners and escalator waiting areas—spaces that are more open to fresh air. In sum, Osaka's concourses post-COVID are characterized by faster passenger flows and less idle time in the facilities.

The case of West Japan Railway concourse shops reflected many of the same dynamics but in a commercial context. Passenger traffic in 2021–22 was significantly lower than in 2008. Across the 13 stations studied, the average daily number of passengers decreased by about 15%. Meanwhile, shop usage dropped even more sharply. At seven stations where store locations remained the same, the number of shop visitors decreased by 25–88% at six stations, with only one station experiencing a slight increase in restaurant visitors. Convenience stores and food vendors that were busy during rush hours were notably underused; only shops located right next to ticket gates maintained consistent foot traffic. For instance, a small kiosk beside the central gates maintained about 80% of its pre-pandemic traffic, while stores in secondary concourse corridors experienced declines of 70–85% in customers per hour. Importantly, we noticed a timing effect: the largest drops in shop customers occurred during morning and evening rush periods, suggesting that remaining passengers hurried directly to trains without stopping for shopping. Overall, the data from the concourse shops show that essential transit functions mostly stayed stable, while discretionary shopping and browsing virtually disappeared.

Collectively, these three case studies reveal common behavioral patterns. Spatially, people moved to areas seen as safer or less crowded: open, well-ventilated spaces gained visitors, while enclosed central halls and traditional waiting spots saw fewer people. Demographically, post-COVID users leaned toward older commuters and essential travelers—those with fixed routines or urgent needs—while leisure and youth travel decreased. Time-based patterns also changed: activity on non-workdays and off-peak times (weekends, midday) was especially reduced. For example, Himeji Station front plaza showed a stronger link between daily visitor numbers and station ridership on weekends than on weekdays, suggesting weekend leisure trips decreased more than the typical weekday commute. Overall, the pandemic seems to have filtered transit spaces, focusing usage on the most critical flows and spreading stationary activities to the edges.

These findings echo worldwide observations: transit ridership fell “precipitously” across the globe, and open plazas were among the few spaces that remained actively used. In our data, station plazas and concourses were utilized far less for social gatherings than before, aligning with the literature’s focus on shorter stays and smaller groups in these spaces. However, by 2022, some bounce-back was apparent—for instance, Himeji Station front plaza shows more social activity than at the pandemic’s peak, though still below pre-2020 levels. The ongoing trend reflects adaptation rather than reversal: many travelers have adopted new habits in their transit routines.

5.2 Discussion

The observed shifts in station-space behavior have significant theoretical implications for urban design and resilience planning. Our case studies demonstrate key themes from spatial theory and behavioral design. First, the role of public plazas as ‘third places’ is under pressure. Classic urban theorists like Jacobs highlight plazas and concourses as sites for incidental encounters and exchanges. The Himeji and Osaka data show that these social uses have become more tentative: people still seek seating and interaction, but only if safety is clearly evident. This aligns with literature noting that visitors’ post-COVID “gravitate toward spots that permit spacing.” It emphasizes the importance of designing plazas with distributed seating and multiple small gathering niches instead of one central crowded zone. In practice, our findings support the idea (Stevens et al., 2021) of modular, reconfigurable layouts—such as movable benches or planters that can be spread out—which mirrors how passengers naturally shifted toward edges and dispersed nodes in our observations.

Second, behavioral design principles are confirmed. Our findings highlight how small-scale design elements—such as bench placement, pedestrian flow paths, and visibility—shape user choices. For example, at Himeji, the Lawn Area’s long, oriented benches (areas A-3/A-4) stayed popular for resting and chatting, indicating that seating suitable for small groups can be acceptable if spaced out. Conversely, common gathering spots like the central stage and fountain were used less after the pandemic. This suggests a rule of thumb: people instinctively seek the “socially responsible path,” choosing routes or locations that offer more space. Designers can use this by guiding movement with wayfinding arrows or slightly angled seating to promote social distancing. In fact, implementing touchless technologies and signage, as recommended by Stevens et al. (2021), becomes especially important. For instance, we saw how Osaka concourse users often avoided rest corners altogether—a clear sign that passive waiting has become a learned behavior. Adding digital signs showing real-

time seating availability or crowd levels could help manage this behavior, turning unconscious avoidance into an informed choice.

Third, from an urban spatial theory perspective, our findings confirm the importance of mixed-use resilience in station areas. Dai et al. (2024, 2025) suggest that stations which serve as transit hubs and also function as mixed commercial centers recover more effectively. Our West Japan concourse case highlights this: stations with diverse retail options (food, bookstores, clinics) performed better, as passengers continued to make essential stops even during COVID-19 surges. In contrast, stations with a mono-functional layout experienced sharper declines in activity. This aligns with the idea of the “15-minute city” and transit-oriented development: if a station can meet multiple daily needs, it sustains foot traffic even when commuting decreases. In fact, our data indicate that stations with shops near platform edges lost fewer customers than those with shops tucked away. This offers an urban planning insight: a spatial layout that blends circulation paths and amenities creates redundancy during crises.

Finally, the pandemic’s impact on resilience planning is evident. Resilience here means the ability of transit environments to absorb shocks (Jenelius, 2022). Our case studies show that simply restoring ridership is insufficient; station design must adapt to new user expectations. For example, Jenelius (2022) argues that resilience isn’t about returning to the 2019 normal but about adjusting to lasting change. In our context, that means designing concourses not just for peak passenger flow but also for multipurpose flexibility. This could include reserving sections of a concourse for quick reconfiguration or ensuring that HVAC systems can handle different density scenarios. Likewise, Afrin et al. (2021) highlight “inclusive” pandemic-resilient planning—supporting the needs of vulnerable groups who rely on transit. In our observations, we noticed that elderly users were more likely to stop and sit. If planners consider such groups explicitly—for example, by providing more covered seating near staircases—then station areas become safer and more equitable.

In summary, the pandemic-driven behavior changes at these West Japan stations reinforce key design and planning principles: flexible, human-centered spaces, guided flows, and multifunctionality. They also suggest improvements: for instance, behavioral design in stations should now consider “avoidance psychology,” intentionally offering alternative pathways and auxiliary waiting areas so that no one is forced into a crowded spot. As one review notes, different age and user groups have varying spatial preferences; our findings reflect this. Therefore, deeper theoretical integration involves combining classic public-space theory (Jacobs, Gehl) with modern resilience thinking. Urban theorists have long emphasized that

well-used plazas foster social capital; COVID-19 has demonstrated that maintaining that function under stress demands design innovation. The changes we observe aren't mere anomalies—they indicate a shift in the public's perceived geography of safety. Post-pandemic transit environments are likely to keep evolving under this influence, and our study highlights the new factors that planners need to consider.

CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This study aimed to analyze how the COVID-19 pandemic has altered human behaviors in the station areas of West Japan Railways, focusing on three key locations: Himeji Station Front Plaza, Osaka Monorail concourses, and West Japan Railway concourse shops. Our main research questions were: How did stay durations, activity types, and spatial use change? Who changed their behaviors the most? We compared detailed observational and survey data from before the pandemic (2008–2017) with post-pandemic snapshots (2021–2022), using heatmaps, flow analyses, and regression methods.

The main findings are summarized as follows: stay patterns shortened across all sites. Station plazas and concourses, which once supported leisurely lingering, are now places of brief pauses. For example, our heatmaps show that in 2022, average dwell times in Himeji's Lawn Area decreased compared to 2017, and Osaka concourse bench stops declined sharply. Spatial distributions shifted: in Himeji, visitors moved from wide-open lawns to peripheral shaded edges (Castle Garden areas D1–F) where spacing was easier. Similarly, Osaka Monorail users favored platform-adjacent rest spaces over large concourse halls. Facility usage declined significantly, except for essentials. Shops in West Japan Railway concourses experienced dramatic declines in customers, especially retail and food outlets; only shops near ticket gates kept moderate use. Demographically, the traveler profile became "essentialized." After COVID-19, non-urgent travelers (students, tourists, casual shoppers) largely disappeared from station spaces, leaving mainly commuters, workers, and older adults. For example, Himeji's youth and child populations decreased more than the middle-aged and elderly populations.

Methodologically, these conclusions originate from combining spatial analysis (heatmaps and area observations) with behavioral categories and regression models. Seasonal and weekday/weekend factors were controlled by matching survey periods, and the KDDI mobile data verified that station-level population decreases align with observed behavioral drops. Qualitatively, our field observations confirmed that people explicitly avoid clusters: mask-wearing was widespread, and many interviewees said they spent the shortest possible time inside stations.

In addressing our objectives, we have shown that the pandemic did not completely shut down station life but rather transformed it. Public spaces in front of transit hubs still hold value, but their use has become more selective and temporary. These findings fulfill the study's goal of identifying what changed (less stay time, altered flows), who changed (commuters vs. others), and where these changes happened (edges vs. centers). The work thus offers a comprehensive, empirically based portrait of post-pandemic station usage, which in turn provides a foundation for design and policy adjustments.

6.2 Recommendations

Based on our findings and the theoretical insights above, we provide the following recommendations for post-pandemic station planning and management. They are organized at multiple levels—from designing individual plazas and concourses to implementing broader policy measures—and emphasize spatial flexibility, digital integration, public health, and user experience.

1) Flexible spatial design: Station areas should be adaptable to respond to changing health needs. As Stevens et al. (2021) suggest, installing modular elements (movable benches, planters, partitions) allows managers to quickly adjust circulation paths. For example, seating in the Himeji Station front plaza could be on tracks so chairs can be easily rearranged. Similarly, in concourses, floor surfaces could be marked with adjustable “walking corridors” that can be reconfigured for distancing during health alerts. Sheltered canopy spaces (like the Castle Garden) could have roll-down clear curtains to open or close airflow as needed. The key is designing all station furniture and fixtures to be multi-purpose: a street bench that can serve as a busking spot on a regular day but be easily moved to increase circulation during an outbreak.

2) Enhanced digital infrastructure: We suggest implementing real-time crowd monitoring and information systems. Since many station-goers carry smartphones, integrating Wi-Fi/Bluetooth sensing or dedicated cameras can track occupancy levels at seating areas and concourses. Simple digital displays or apps could then alert travelers about underused zones. Furthermore, contactless services should be expanded. Our data indicate that people avoid touch-heavy interactions; therefore, adding more touchless ticket gates and mobile QR-code menus for retail in concourses can minimize unnecessary contact. Stations could also introduce virtual queuing systems for popular shops. These digital solutions not only boost health safety but also improve user experience by reducing perceived risks.

3) Public health integration: Health measures should become seamless, permanent features of station environments. For instance, sanitation stations ought to be placed at all concourse entrances and near seating clusters. Instead of temporary stands, these should be designed to blend with station aesthetics. Air quality sensors could also be installed in enclosed waiting areas and restrooms, with displays or ventilation adjustments triggered if CO₂ or particulate levels rise. Stations' cleaning and maintenance schedules should remain intensified post-pandemic, especially for high-touch surfaces. For example, routine cleaning logs could be digitalized and made publicly visible to reassure users. On a policy level, building codes could be updated to require pandemic-proofing, drawing from guidelines like those advocated by Afrin et al. (2021).

4) Enhancing user experience: We should not sacrifice comfort or community for safety. Our observations show that people still prefer short social interactions, such as phone chats and quick meals, at stations. Therefore, stations should offer both ample seating and clear signage to promote healthy usage. Simple measures like floor graphics indicating 1-meter distancing or one-way walking arrows in hallways help establish good habits without heavy enforcement. Signage in multiple languages with clear icons is essential for a diverse user base (tourists, elderly). Incorporating art and green spaces can also enhance the experience: living walls or small gardens in plazas can attract people outdoors and provide cues for fresh air. Most importantly, planners should seek user feedback after implementation; regular surveys or digital or physical suggestion kiosks can help refine these interventions.

These recommendations are based on our field observations and broader research on pandemic-resistant design. For instance, using tactical urbanism strategies during COVID-19 has shown success in many cities (Stevens et al., 2021). We stress that a single intervention is not enough; a layered strategy—combining spatial adjustments, technology, and policy—is essential. In the post-pandemic period, station environments should be viewed as adaptable infrastructures that can evolve with societal needs, maintaining safety and vibrancy.

6.3 Limitations

This study has several limitations. Methodologically, we relied on two snapshots in time for most of the data—one before the pandemic and one after. As a result, short-term fluctuations or intermediate recovery trends are not captured; our comparisons (2008 vs. 2021, 2017 vs. 2022) implicitly assume that unobserved years followed a relatively smooth trajectory. Additionally, the long gap between surveys (13 years for the concourse-shop study) means that factors other than COVID-19 could influence the results. While we

attempted to control for known changes, not all external influences could be measured. In the post-pandemic surveys, all on-site field observations were conducted by a single trained observer. This helped maintain consistency with earlier survey protocols but also introduced the potential for observer bias and limited the amount of behavior that could be recorded during busy periods; some short stays or subtle interactions may have been missed. For ethical and privacy reasons, we did not use photographs or video recordings in the Himeji Station Plaza or Osaka Monorail concourses. Therefore, the analysis relies on manual tallies, sketch maps, and written notes, which constrain the spatial and temporal resolution of individual trajectories and micro-behaviors. Furthermore, demographic attributes such as age group were estimated visually rather than obtained through interviews. Although similar age categories and coding rules were applied across survey years, differences in individual judgment between periods cannot be fully ruled out. Age-related findings should therefore be considered approximate and comparative rather than exact. Future research should complement our on-site methods with anonymous sensor data or smartphone-based mobility data to validate and extend these findings.

Our case studies are all located in Kansai (West Japan) and may not apply to other regions or countries. Stations in large cities like Tokyo or in rural areas could show different patterns because of different user demographics and built environments. For example, we looked at stations with commercial concourses; stations that are mostly suburban and lack shops might behave differently. Comparing different cities or countries would help determine if our findings are universal. Additionally, climate and seasonal changes could affect outdoor plaza use; studying winter or rainy season behavior would give a more complete understanding.

Data and time frame are additional limitations. Our KDDI mobile data analysis at Himeji provides useful trends but is limited by that single operator's market share. Additionally, we could not access high-frequency ridership data for the entire pandemic period. More detailed data, such as monthly passenger counts, could allow time-series models to distinguish pandemic impacts from, for example, economic downturns. Similarly, our West Japan Railway shop study used passenger counts and one-hour surveys; ongoing or long-term monitoring of foot traffic would improve understanding of when and why people stopped visiting shops.

6.4 Future Works

Given these constraints, several promising avenues for future research emerge:

1) Advanced behavioral modeling: Agent-based simulations or pedestrian dynamics models can test how proposed design changes might affect behavior. Researchers could calibrate these models with our observed pre- and post-pandemic movement data to simulate hypothetical interventions. For example, Liu and Kaneda's (2021) agent simulations of station crowding suggest that small layout adjustments can significantly reduce close contact; applying similar methods to our case sites could help identify optimal designs.

2) Technology-assisted monitoring: Future studies might use emerging tools—such as thermal or LiDAR sensors—to continuously observe station usage and detect patterns not visible through manual surveys. Incorporating GPS-based mobility data or Wi-Fi probe requests could allow real-time tracking of how people enter, exit, and move within areas. This method would also facilitate international comparisons: by using standardized mobile data, researchers could compare, for instance, Himeji with stations in Tokyo or other cities worldwide under different policy conditions.

3) Longitudinal and event-based analysis: Ongoing observation in the coming years will show which changes last. For example, if remote work becomes semi-permanent, how will that change the use of station plazas? Future studies could follow the recovery paths of these spaces—building on ideas from transit resilience research. Event-based research could evaluate how well interventions like crowd alerts or sanitation campaigns work during different stages of recovery.

4) Refined design principles – emphasizing spatial diversity: The Himeji case indicates that users adapted by spreading activities across sub-areas with different qualities. This indicates that spatial diversity should be a main resilience principle alongside flexibility and digital infrastructure. Future research needs to define diversity and examine how it supports daily comfort and shock resilience. For 2025–2026, recommendations should focus on long-term value: design spaces that remain attractive in normal times while still allowing quick reconfiguration when necessary.

5) Institutional and policy considerations: Chapter 2 showed limited shop loss across 13 stations, indicating that outcomes depend not only on behavior and spatial structure but also on institutional capacity and policy support. Future research should incorporate governance and economic mechanisms into station resilience analysis: compare operators and regions with different support programs, measure how policy buffers commercial decline, and explore how institutional design interacts with spatial factors to influence recovery trajectories.

6) User-centered surveys and qualitative research: Finally, direct surveys or interviews with passengers can enhance our understanding of motivations. Why did certain individuals

resume using station spaces or shops in 2022 despite risks? Understanding subjective perceptions would complement our observational data. Ethnographic studies might also explore how people feel about permanent safety features. Combining quantitative and qualitative insights will be essential for creating truly user-friendly and resilient transit spaces.

In conclusion, while our study provides a solid cross-sectional analysis of how COVID-19 changed station-area behavior, it also opens the door for a broader research agenda. The mid-2020s context encourages us to look beyond just the immediate pandemic response and focus on maintaining vibrant, adaptable transit environments over the long term. By utilizing new data tools, expanding our design frameworks, and incorporating policy and user perspectives, researchers and practitioners can work together to develop a comprehensive plan for resilient station spaces. This agenda is forward-looking: it aims not only to make stations pandemic-proof but also to ensure these public spaces continue to thrive as centers of community and mobility amid whatever changes the future may bring.

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Appendix 1

Base Map for Field Observation at Himeji Station Front Plaza to Record Visitor Basic and Location Information

