Master’s degree programme in

TERRITORIAL, URBAN, ENVIRONMENTAL AND LANDSCAPE PLANNING

MASTER THESIS

Evaluating Transit-Oriented Development (TOD) Challenges and Prospects in Tehran:

A Focus on Land Use Strategies around Metro Stations

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Abstract

As global cities grapple with the pressures of rapid urbanization and environmental degradation, the pursuit of integrated, sustainability-driven planning models has become a strategic priority. Transit-Oriented Development (TOD), which emphasizes the alignment of land use and public transport infrastructure, is increasingly recognized as a viable framework for fostering compact, accessible, and low-carbon urban growth.

With an emphasis on land use strategies surrounding metro stations, this thesis examines the opportunities and difficulties of implementing TOD in Tehran. Despite significant investments in the development of Tehran's metro system, the land use in nearby neighborhoods - which is typified by low-density development, monofunctional zoning, and restricted pedestrian accessibility - remains inadequately integrated with the transit infrastructure. Using a mixed-methods approach, the study evaluates 124 metro stations using the 5D framework - Density, Diversity, Design, Destination Accessibility, and Distance to Transit - by combining fieldwork, policy review, and GIS-based spatial analysis. K-means clustering and entropy-based indicator weighting were used to define station typologies and pinpoint performance gaps. After a comparative case study analysis, a redesign proposal based on TOD principles and tailored to local conditions was developed for the lowest-performing station (HEMAT). The results emphasize how outdated zoning laws, institutional fragmentation, and sociocultural preferences affect the viability of TOD. To improve TOD implementation in Tehran and direct future sustainable urban development, the thesis ends with strategic recommendations for integrated governance, incentive-based financing, community-oriented planning, and regulatory reform.

Keywords

Transit-Oriented Development (TOD) - Land Use Planning - Metro Stations - Sustainable Urban Development – Tehran - Public Transportation -Mixed-Use Development

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Abbreviations

AHP Analytic Hierarchy Process

A structured decision-making method used to prioritize criteria based on pairwise comparisons.

BRT Bus Rapid Transit

A high-quality bus-based transit system offering fast, efficient, and reliable urban mobility.

ESRI Environmental Systems Research Institute

A global leader in GIS software development, known for creating ArcGIS.

FAR Floor Area Ratio

A planning metric that defines the ratio of a building's total floor area to the size of its plot.

GIS Geographic Information System

A technology platform for spatial data analysis, mapping, and visualization in planning.

IAD Institutional Analysis and Development Framework

A conceptual model for analyzing institutional arrangements and governance structures.

ITDP Institute for Transportation and Development Policy

A global organization promoting sustainable and equitable transportation solutions.

LUP Land Use Planning

The process of regulating land development and organizing urban space functions.

LVC Land Value Capture

A financing mechanism that recovers increased land values generated by public investment.

MCE Multi-Criteria Evaluation

A decision-support tool that assesses alternatives based on multiple weighted factors.

MOI Ministry of Interior

The national government body responsible for urban transport policy and municipal affairs in Iran.

MRUD Ministry of Roads and Urban Development

Iran's central authority managing national transport infrastructure and urban development.

NMT Non-Motorized Transport

Modes of transport such as walking and cycling that do not involve motorized vehicles.

PBO Plan and Budget Organization

A governmental institution in Iran responsible for national development plans and budget allocation.

PPPs Public–Private Partnerships

Collaborative financing and development arrangements between governments and private sector actors.

SCUPA Supreme Council of Urban Planning and Architecture

Iran's top policy-making body for urban planning, regulation, and architecture.

SDG Sustainable Development Goals

A set of 17 global objectives adopted by the United Nations to guide sustainable global development.

SWOT Strengths, Weaknesses, Opportunities, and Threats

A strategic planning tool used to evaluate internal and external factors affecting a project or policy.

TIF Tax Increment Financing

A development tool that uses future tax revenue increases to fund current infrastructure improvements.

TOD Transit-Oriented Development

A planning approach that promotes compact, mixed-use development within walking distance of transit stations.

ULI Urban Land Institute

A global nonprofit research and education organization focused on responsible land use and development.

VTM Vehicle Travel Management

A strategy aimed at optimizing and reducing private vehicle use through traffic and demand management.

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Chapter 1
Introduction

1.1 Background of the Study

Urbanization and rapid population growth in major cities worldwide have posed significant challenges to sustainable urban development. As urban areas expand, problems related to traffic congestion, environmental degradation, insufficient infrastructure, and social inequality intensify, especially in developing countries (UN-Habitat, 2020). One of the most effective planning approaches to address these challenges is Transit-Oriented Development (TOD), which integrates land use and transportation to create compact, walkable, and mixed-use communities around high-capacity transit systems (Cervero, R & Murakami, J, 2010).

TOD aims to reduce dependence on private vehicles, encourage public and non-motorized transport, and promote efficient land use through high-density and mixed-use development. These principles help enhance accessibility, improve urban livability, and reduce environmental impacts such as air pollution and greenhouse gas emissions (Dittmar & Ohland, 2004; Newman & Kenworthy, 2015).

Tehran, the capital of Iran and one of the largest cities in the Middle East, is a prime example of the urban pressures arising from rapid and often uncoordinated growth. Over recent decades, Tehran has experienced uncontrolled urban sprawl, excessive car dependency, and fragmented land use patterns, resulting in environmental stress, inefficient transport networks, and declining quality of life. The Tehran Metro, inaugurated in 1999, has significantly expanded in recent years, offering a vast network aimed at improving mobility and reducing road congestion. However, land use around many metro stations fails to align with TOD principles. Most stations are surrounded by low-density, mono-functional land uses, poor pedestrian environments, and limited mixed-use services - factors that reduce the efficiency and social vibrancy of these transit nodes (Mirmoghtadaee, 2016).

Globally, TOD has been recognized as a powerful catalyst for sustainable urban development, contributing to reduced travel demand, revitalized urban areas, enhanced social equity, and environmental improvements (Suzuki et al., 2013). However, in many cities, including Tehran, TOD implementation faces barriers such as weak governance, lack of integrated planning, financial constraints, and socio-cultural resistance to high-density living (Bertolini et al., 2012).

Mirmoghtadaee (2016) argues that all these factors provide a context in which TOD could play an important role in reducing car dependency in Iran. She also highlighted three basics obstacles facing the development of TOD in Iran: (1) the need for an Iranian version of TOD, (2) low priority given to the integration with transport infrastructure in national housing strategies, and (3) overlapping and parallel institutions and insufficient planning instruments.

There are other studies in which TOD in Iran has been under focus of attention, including the small number of local, case-based research works. These studies were conducted throughout different cities nationwide, where basic physical dimensions of TOD (i.e. 3Ds) were examined qualitatively and quantitatively, regardless of the policy and procedural frameworks (e.g. Alizadeh et al., 2013; Asadollahfardi et al., 2015; Abbaszadegan et al. 2011; Behzadfar & Zabihi, 2011; Rafieian et al., 2010; Montazeri, 2012, Kheiroddin et al., 2014; Motieyan & Mesgari, 2017; Motieyan & Mesgari, 2019; Mirmoghtadaee & Adli,2018). In this respect, there are some relevant gaps that could be filled with an in-depth research, in order to be able to answer questions such as: “what are the prospects and challenges associated with planning TODs in Iranian cities, or to what degree such plans could achieve success?”

Currently, the Iranian central government, policymakers and few municipal officials are seriously attempting to turn the car-based transportation and urban planning models into the sustainable ones. Developing metropolitan public mass transit means, such as subway systems and BRT in large cities, and its associated policies and institutions, and more recently, approving a national guideline for TOD are some examples. These all portray the officials' enthusiasm to apply transit-oriented strategies in the Iranian cities, on the other hand, something that has been recommended by Iranian academic bodies for many years. A national TOD approach implies that, as with many other countries, the problems in Iran are not only related to just a set of imperfections in public transit services, but also needs development integration in order to achieve sustainability.

In Tehran, these challenges are evident in the form of institutional fragmentation, regulatory gaps, land market distortions, and cultural preferences for low-rise, car-oriented development. Moreover, the absence of empirical, location-specific assessments and data-driven policy models hampers efforts to implement TOD effectively. This underscores the need for in-depth studies that evaluate TOD potential, especially around metro stations, where opportunities for transformation are most promising (Shahmoradi et al., 2020).

This research addresses this gap by critically analyzing the current land use conditions around Tehran’s metro stations to identify challenges, potentials, and practical strategies for TOD-based development, with the ultimate goal of informing sustainable urban planning policies.

EVOLUTION AND DEVELOPMENT TIMELINE OF TEHRAN METRO SYSTEM

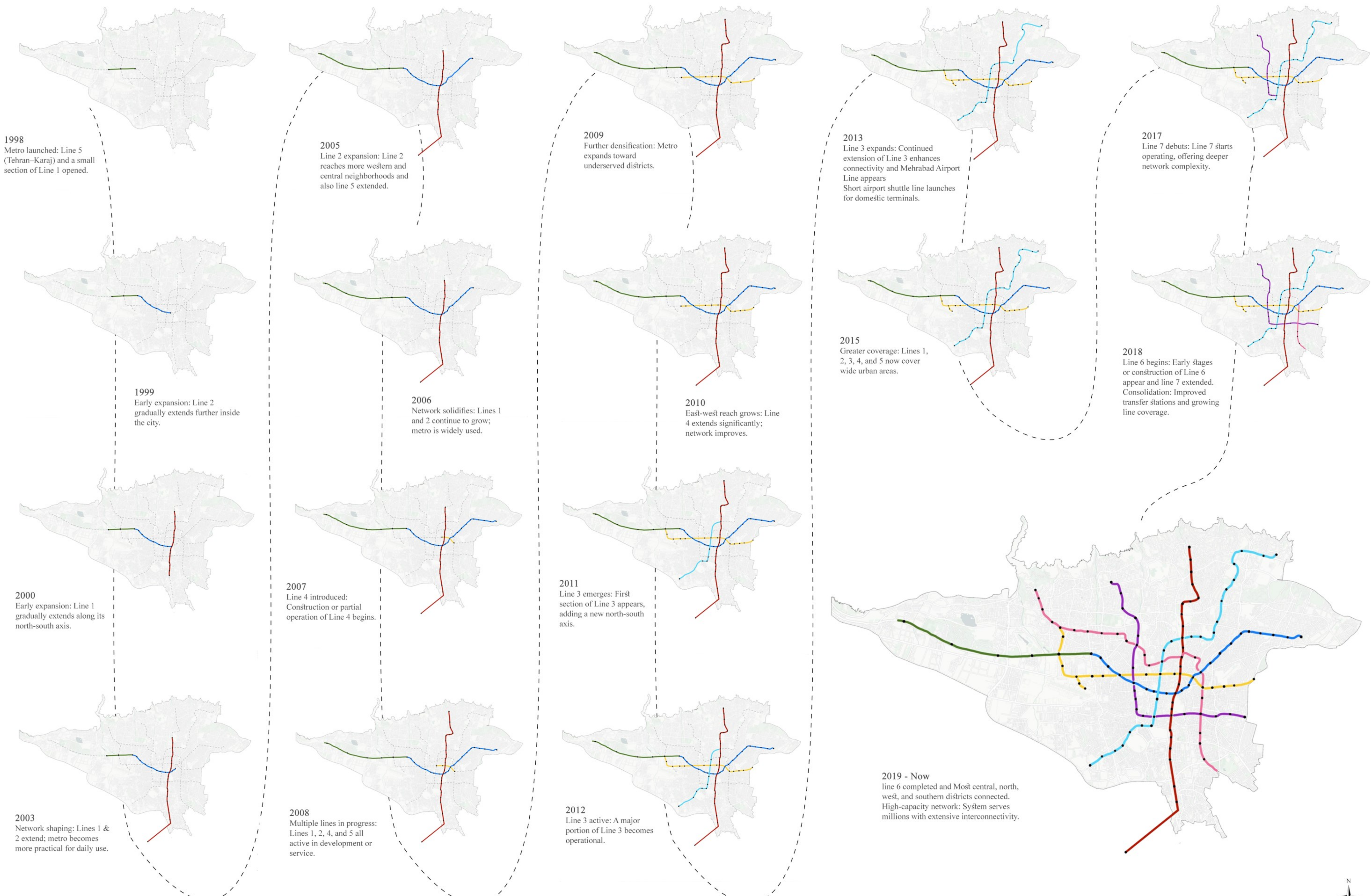


Figure 1 Evolution and development time line of Tehran metro system

1.2 Significance and Justification of Research

The increasing urban population, spatial expansion, and environmental pressures in Tehran call for a paradigm shift in urban planning approaches. This research, focusing on the potential of Transit-Oriented Development (TOD), is significant in providing localized, data-driven strategies to address Tehran's urban challenges. The justification lies in three interlinked dimensions:

1.2.1 The Impact of TOD on Reducing Traffic Congestion and Pollution

Tehran, one of the most congested cities in the world with over 17 million daily trips, faces one of the highest levels of congestion and air pollution in the region. Over 70% of these trips are made by private vehicles, leading to heavy fuel consumption and serious public health risks due to poor air quality. For example, Tehran recorded over 120 days in 2023 with air pollution levels classified as unhealthy for sensitive groups (Tehran Municipality, 2023). The severe congestion contributes to extensive fuel consumption, greenhouse gas emissions, and deteriorating air quality, which has become a public health crisis. Implementing TOD in Tehran could significantly enhance public transport accessibility, reduce reliance on private vehicles, and improve overall environmental conditions. Beyond its environmental benefits, TOD can also serve as a transformative tool for improving urban livability and advancing social equity.

Studies indicate that TOD-oriented cities have lower per capita vehicle miles traveled [1] (VMT), which directly reduces CO_2 emissions and urban pollution (Newman & Kenworthy, 2015). In cities like Singapore and Curitiba, TOD has contributed to cleaner air, more efficient transportation, and improved public health outcomes.

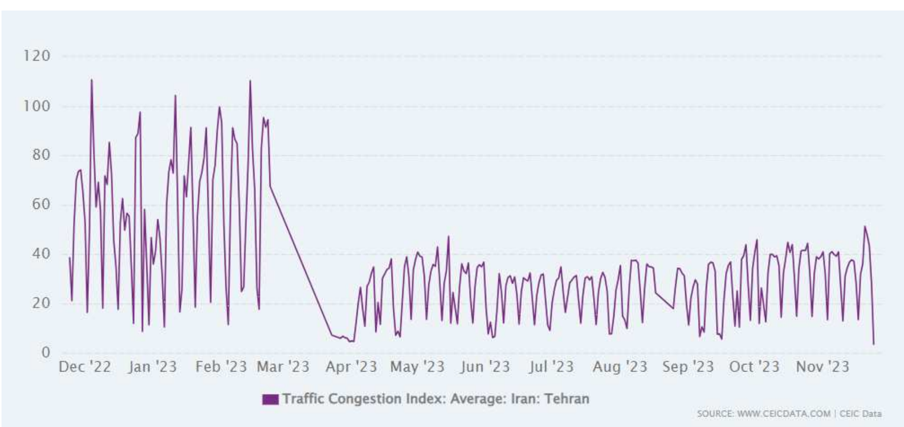


Figure 2 Average of Traffic Congestion in Tehran 2024

[1] The average distance traveled by a person using a vehicle over a set period; lower VMT indicates reduced car use and more sustainable urban form. (Ewing & Cervero, 2010)

1.2.2 Enhancing Urban Livability and Social Equity Through Land Use Planning

Transit-Oriented Development (TOD) provides a comprehensive framework for creating more sustainable, inclusive, and livable urban environments. It emphasizes compact, mixed-use, and pedestrian-friendly neighborhoods centered around high-capacity public transport hubs. By integrating residential, commercial, educational, healthcare, and recreational uses within walking distance of transit, TOD reduces long commutes, promotes active transportation, and enhances access to daily services. This spatial configuration fosters social interaction, street vitality, and public safety, contributing to overall urban quality of life (Cervero et al., 2017; UN-Habitat, 2022; Dittmar & Ohland, 2012).

Importantly, TOD can promote social equity by improving access to jobs, education, and healthcare for populations who lack private vehicle access. Ensuring that lower-income residents can live near well-connected transit areas helps reduce transport poverty and support upward mobility. When coupled with affordable housing and inclusionary zoning policies, TOD encourages social mixing and improves life opportunities for marginalized groups (Zhao et al., 2021; Suzuki et al., 2013; ITDP, 2020).

In contrast, Tehran's urban landscape is dominated by low-density, single-use zoning and fragmented spatial structures. Many neighborhoods are either residential or commercial, with little integration between them. This segregation leads to inefficient urban form, increased traffic, and reduced community interaction (Shahmoradi et al., 2020; Mirmoghtadaee, 2016). Around many metro stations, the lack of mixed-use development and poor pedestrian infrastructure discourages walking and underutilizes public transit (World Bank, 2022; Tabrizi & Arjmandi, 2020).

Adopting TOD principles could enable Tehran to transform its metro station areas into vibrant urban centers - places where living, working, and social activities are seamlessly integrated. This would boost transit ridership, reduce car dependency, and enhance urban livability and environmental quality (ITDP, 2020; Suzuki et al., 2013; Bertolini et al., 2012). Global examples from cities like Portland and Singapore demonstrate that TOD can lead to shorter commutes, better transit access, and lower emissions - outcomes especially relevant to a city of Tehran’s scale (Curtis et al., 2020; Givoni & Banister, 2013).

The contrast between Tehran’s current development model and TOD-oriented cities is stark. While Tehran faces sprawl, congestion, and poor walkability, TOD offers a path toward more connected, resilient, and equitable urban development. Achieving this vision will require substantial reforms in land use planning, but the long-term benefits for accessibility, social integration, and sustainability are significant (UN-Habitat, 2022; Zhao et al., 2021; Bertolini et al., 2012).

1.2.3 Addressing TOD Implementation Barriers in Tehran

Despite its potential as a sustainable urban growth model, the implementation of Transit-Oriented Development (TOD) in Tehran faces several major obstacles.

A primary challenge is institutional fragmentation. Responsibilities for transportation, housing, land use, and urban development are spread across multiple agencies - such as the Tehran Municipality, the Ministry of Roads and Urban Development, and various district authorities - leading to uncoordinated planning, conflicting priorities, and limited integration (Bertolini et al., 2012).

Outdated zoning regulations also hinders TOD. Tehran's current urban codes often restrict mixed-use development and higher residential densities near metro stations, limiting the ability to create compact, walkable communities that encourage transit use (Mirmoghtadaee, 2016; Shahmoradi et al., 2020). Without regulatory reform - such as flexible zoning and density bonuses - TOD cannot be effectively realized.

Cultural and behavioral resistance adds a further layer of complexity. Many residents, particularly from middle- and upper-income groups, prefer low-density, car-oriented lifestyles and view high-rise living negatively due to concerns over noise, crowding, and perceived loss of quality of life (Mirmoghtadaee, 2016; Shahmoradi et al., 2020). Private vehicles remain the dominant travel mode, often considered safer and more convenient than public transport.

From an economic standpoint, limited financial incentives discourage developer investment in TOD-compatible projects. Developers often favor short-term profitability and avoid the risks associated with mixed-use, high-density construction near transit nodes. The lack of mechanisms such as subsidies, tax incentives, or public-private partnerships further undermines TOD's financial viability (Bertolini et al., 2012).

Addressing these barriers requires an integrated, multi-level governance framework that aligns planning goals across institutions. This must be supported by regulatory reform, including updated zoning laws that permit TOD-compatible land uses (Shahmoradi et al., 2020). Financial tools - such as density bonuses, value capture, and development rights transfers - should be introduced to incentivize private sector engagement (Mirmoghtadaee, 2016). Equally important is sustained community engagement to raise awareness about the benefits of TOD and to address public concerns regarding densification and transit use.

Ultimately, as Bertolini et al. (2012) argue, TOD success depends not only on technical planning but also on political commitment and the cultural adaptation of policies to local urban realities.

1.3 Problem Statement

Tehran's rapid urban expansion over recent decades has resulted in sprawling development, traffic congestion, air pollution, and increasing socio-spatial inequalities. Although substantial investments have been made in public transit - particularly the metro system, now comprising over 150 stations - these efforts have not resolved the city's persistent urban challenges. This reflects a critical gap between infrastructure provision and integrated urban planning.

Transit-Oriented Development (TOD) offers a proven framework to address these issues by promoting compact, mixed-use, and walkable neighborhoods centered around transit hubs. Yet, in Tehran, TOD principles remain largely under-implemented due to a combination of spatial, institutional, economic, and cultural barriers that impede the integration of land use and transit planning.

1.3.1 Lack of Coordination Between Transit and Land Use Planning

A fundamental barrier to effective TOD in Tehran is the weak coordination between metro expansion and urban land use planning. While TOD is intended to create dense, walkable, and mixed-use neighborhoods around transit nodes (Calthorpe, 1993; Khosravi et al., 2024), many of Tehran's metro station areas - particularly in peripheral and southern districts - remain underdeveloped or dominated by low-rise, single-function uses (Motieyan & Mesgari, 2017).

These areas often lack the necessary land use diversity and density to support high transit ridership or vibrant urban life (Mirmoghtadaee, 2016; Khosravi et al., 2024). Physical barriers such as dead-end streets, wide highways, and enclosed housing blocks further reduce accessibility and limit walkability near metro stations (Hosseini et al., 2022). As a result, many stations fail to function as integrated neighborhood centers or catalysts for development.

The situation is exacerbated by outdated and inflexible zoning regulations, which restrict mixed-use development and hinder vertical land use integration - such as residential-over-retail configurations central to TOD (Mirmoghtadaee & Abdi, 2021). Without regulatory tools that support adaptive, transit-oriented growth, station areas remain disconnected from the urban fabric and fail to generate meaningful transformation.

1.3.2 Institutional and Regulatory Barriers

The institutional structure of Tehran's urban governance is another key impediment to TOD. The planning, construction, and regulation of transit and land use are managed by a wide range of actors - including the Tehran Municipality, the Ministry of Roads and Urban Development, the Tehran Urban and Suburban Railway Company, and local district offices - each with distinct priorities, overlapping jurisdictions, and limited mechanisms for coordination (Mirmoghtadaee & Abdi, 2021).

This fragmented governance system undermines the integrated, cross-sectoral approach that TOD demands. In practice, transit agencies focus on rail expansion without aligning plans with land use strategies, while urban planning departments often operate independently of transit projects. Consequently, metro stations are built without corresponding urban design, public realm improvements, or redevelopment plans for adjacent parcels. Even when TOD policies are introduced - such as the 2021 national guideline - they often remain symbolic, with limited practical enforcement capacity or institutional support at the municipal level (Mirmoghtadaee & Abdi, 2021; Mirmoghtadaee, 2016).

Moreover, Tehran's planning system continues to rely on master plans and static zoning codes that are poorly suited for adaptive, place-specific TOD interventions. These outdated frameworks lack the flexibility to incentivize TOD-supportive densities or land use mixtures and fail to integrate criteria such as accessibility, public realm design, or walkability into development assessments (Motieyan & Mesgari, 2017; Khosravi et al., 2024).

1.3.3 Financial Constraints

Financial limitations also pose significant barriers to TOD implementation in Tehran. Transforming metro station areas into TOD-friendly environments requires substantial public investment in infrastructure, streetscape improvements, pedestrian facilities, and public spaces. Yet, due to macroeconomic constraints, inflation, and budgetary pressures, Tehran's urban development funding is often insufficient or inconsistently allocated (Khosravi et al., 2024). Consequently, many stations - particularly in low-income districts - lack basic amenities such as lighting, safety features, and service-oriented commercial spaces, which are essential for creating vibrant transit hubs.

In addition to limited public resources, the private sector remains largely absent from TOD-related investments. This is due to a combination of uncertain regulatory frameworks, weak land management systems, lack of development incentives, and low investor confidence - especially in station areas with limited market activity or poor accessibility (Mirmoghtadaee & Abdi, 2021). Without targeted financial tools such as land value capture, density bonuses, or tax incentives, TOD remains an expensive and high-risk endeavor for private developers.

Furthermore, there is no structured mechanism for capturing the increased land value that typically arises from proximity to transit stations - a practice widely used in TOD policies around the world to finance infrastructure upgrades and affordable housing. In the absence of such mechanisms, opportunities to reinvest in public amenities and equitable development around stations are consistently missed (Mirmoghtadaee, 2016).

1.3.4 Socio-Cultural Preferences and Travel Behavior

The implementation of TOD in Tehran is hindered by deep-rooted socio-cultural and behavioral preferences shaped by decades of car-oriented planning, fuel subsidies, and pro-automobile policies. As a result, private vehicle use remains dominant - even in transit-served areas - contributing to chronic congestion, pollution, and underutilization of the metro system (Salarvandian et al., 2017; Alizadeh & Sharifi, 2023).

Cultural attitudes further reinforce these trends. Many middle- and upper-income residents continue to associate success with low-density, suburban living, detached housing, and exclusive car access. This mindset often leads to resistance against densification, high-rise development, and mixed-use zoning - elements fundamental to TOD (Mirmoghtadaee, 2016; Hosseini et al., 2022).

Compounding the issue is the lack of public awareness about the long-term benefits of TOD, such as improved quality of life, reduced transportation costs, and environmental sustainability. Without community engagement and education, TOD initiatives risk public resistance, especially when they involve changes in land use, reduced parking, or perceived threats to neighborhood character.

Moreover, significant transport inequities persist across socioeconomic groups. Low-income residents often rely on underfunded transit services and live in poorly connected neighborhoods, limiting their access to jobs, education, and essential services (Alizadeh & Sharifi, 2023). These structural disparities reduce the inclusiveness and effectiveness of TOD as a tool for equitable development.

In sum, Tehran's inability to implement TOD effectively reflects more than a lack of infrastructure; it stems from a complex interplay of spatial, institutional, financial, and cultural challenges. The disconnect between metro infrastructure and surrounding land use, coupled with resistance to change and weak governance, continues to constrain the city's shift toward sustainable, transit-oriented urbanism.

This thesis addresses these challenges by focusing on land use strategies around metro stations - analyzing the degree to which current urban forms and zoning align with TOD principles. Through spatial analysis and typology development, the study offers evidence-based recommendations to enhance TOD performance in areas marked by poor integration and socio-spatial inequality.

1.4 Research Objectives

The primary aim of this research is to critically assess the current state of Transit-Oriented Development (TOD) in Tehran, identify key barriers to its implementation, and develop strategic, context-sensitive recommendations to improve TOD planning and policymaking. In pursuit of this aim, the study is structured around three interrelated objectives that reflect the spatial, institutional, and policy dimensions of TOD.

The first objective is to evaluate the existing land use patterns around Tehran's metro stations and determine the extent to which they align with TOD principles. While TOD emphasizes high-density, mixed-use, and pedestrian-friendly environments, many metro station areas in Tehran remain underutilized, characterized by low-density, single-function zoning. To address this, the research will analyze various land use types - such as residential, commercial, and recreational - alongside building densities, zoning codes, and urban design policies. A GIS-based spatial analysis will be conducted to assess indicators including population density, floor-area ratio (FAR), land use diversity, and accessibility within defined transit zones. Additionally, walkability, public space quality, and pedestrian connectivity will be evaluated to gauge the physical support for TOD. The findings will be compared against international TOD best practices from cities such as Tokyo, Hong Kong, Copenhagen, and Portland, in order to identify spatial and regulatory gaps and inform context-specific land use interventions.

The second objective is to identify the key barriers that have prevented the effective implementation of TOD in Tehran. Although public investment in transit infrastructure has increased, TOD remains underdeveloped due to a complex mix of institutional, regulatory, financial, and socio-cultural challenges. This part of the research will investigate how fragmented governance structures, lack of inter-agency coordination, and outdated planning regulations have constrained integrated land use–transit planning. It will also explore financial limitations, including high development costs, insufficient municipal funding, and the absence of mechanisms to attract private sector investment. In parallel, the study will analyze socio-cultural resistance to TOD - particularly the preference for low-density, car-oriented living among many Tehran residents - using surveys and stakeholder interviews. Additional attention will be given to the role of land speculation, bureaucratic inertia, and regulatory inflexibility in stalling TOD-related development near transit corridors. Through this analysis, the research aims to construct a comprehensive picture of the systemic obstacles impeding TOD realization.

The third and final objective is to propose strategic recommendations to enhance TOD in Tehran. These recommendations will focus on zoning reform, financial innovation, institutional restructuring, and inclusive policy design to facilitate the development of compact, mixed-use, and transit-integrated urban environments. Key strategies will include revising zoning regulations to support higher-density and multifunctional uses within a 400–800-meter radius of metro stations, and introducing financial tools such as land value capture, tax incentives, and density bonuses to stimulate private sector participation. Furthermore, the study will address the need to improve pedestrian infrastructure, last-mile connectivity, and multimodal access in and around station areas. Institutional recommendations will emphasize the importance of better coordination among planning bodies and may include the establishment of a centralized TOD agency or a cross-sectoral task force. Finally, the research will advocate for more community-driven TOD planning by incorporating affordable housing, public amenities, and environmental considerations into redevelopment strategies. These comprehensive recommendations aim to close the gap between TOD theory and practice and support Tehran's transition toward a more sustainable, inclusive, and efficient urban future.

1.5 Research Questions

The primary research question guiding this study is:

"What are the key challenges and opportunities for effective implementation of Transit-Oriented Development (TOD) around metro stations in Tehran, and how can land use strategies be optimized to support TOD principles?"

This question aims to investigate the existing barriers and enabling factors in TOD implementation in Tehran, considering both policy and urban planning perspectives. It also seeks to identify potential strategies to enhance the effectiveness of TOD, ensuring that metro stations serve not just as transit nodes but as vibrant, integrated urban centers that foster sustainable mobility and urban development.

1.5.1 Key Themes and Sub-Questions

To systematically address this research question, the following key themes and sub-questions have been identified:

Key Themes	Sub-Questions
Evaluating the Current TOD Landscape in Tehran	What are the existing land use patterns and densities around Tehran's metro stations, and how do they compare to TOD principles? How does the lack of coordination between land use planning and transportation planning impact TOD development?
Identifying Barriers to TOD Implementation	What are the institutional and regulatory challenges preventing the integration of TOD principles in Tehran's urban planning framework? How do financial constraints and lack of investment incentives affect TOD feasibility and real estate development near metro stations? What role do public attitudes and socio-cultural factors, including preferences for low-density living and car dependency, play in TOD adoption?
Developing Strategies for TOD Optimization	What policy and zoning reforms can promote higher-density, mixed-use development around transit nodes? How can innovative financing mechanisms (e.g., public-private partnerships, land value capture, tax incentives) help support TOD investments? What urban design and pedestrian-friendly infrastructure improvements are necessary to enhance accessibility and livability around metro stations?

Table 1 Research Themes and Key Sub-Questions
Source: made by author

1.5.2 Research Significance in Addressing the Question

This research holds particular significance as it addresses a major gap in urban planning scholarship concerning Transit-Oriented Development (TOD) in Tehran. Despite the substantial expansion of the Tehran Metro, land use planning around transit stations has not evolved in tandem. As a result, many station areas remain underutilized and disconnected from the broader urban fabric, functioning merely as transit nodes rather than dynamic, high-density urban centers. This study seeks to bridge that disconnect by critically examining the spatial, regulatory, and institutional conditions that shape development around metro stations, and by identifying strategic interventions to better integrate land use and transportation systems.

A key contribution of the study is its detailed analysis of land use inefficiencies and zoning constraints that hinder TOD implementation. By comparing Tehran's existing development patterns and planning practices with global TOD benchmarks from cities such as Tokyo, Hong Kong, and Copenhagen, the research will highlight the spatial and regulatory shortcomings that limit the city's ability to leverage its transit infrastructure for broader urban transformation. These cities have successfully used TOD to integrate dense, mixed-use development with high-capacity transit systems (Suzuki et al., 2013; Cervero et al., 2017), offering practical models for compact, walkable, and economically vibrant station areas.

Another important dimension of this study is its focus on the institutional and financial barriers to TOD in Tehran. Previous research has consistently shown that fragmented governance structures, lack of inter-agency coordination, and regulatory inertia are major impediments to TOD success (Curtis et al., 2009; Guerra & Cervero, 2011). These challenges are especially acute in Tehran, where multiple planning and transportation agencies operate independently, leading to policy misalignment and implementation delays. In addition, limited municipal budgets and insufficient private sector engagement have further constrained transit-adjacent development. This research will investigate alternative financing tools - such as land value capture, tax incentives, and public-private partnerships - that have been effectively applied in cities like Hong Kong and Tokyo (Suzuki et al., 2015), to explore their applicability in the Iranian context.

The study also carries strong social and environmental relevance. In many Tehran neighborhoods, socio-cultural preferences favor suburban, low-density living over compact, transit-oriented development. These attitudes, reinforced by car-centric infrastructure and a lack of walkable public spaces, have inhibited public acceptance of TOD. By examining public perceptions, travel behaviors, and accessibility constraints, the research will offer recommendations to encourage a shift toward more sustainable urban lifestyles. Lessons will be drawn from international examples - such as Stockholm and Singapore - where TOD has been supported through integrated green spaces, pedestrian-prioritized design, and inclusive community engagement programs (Dittmar & Ohland, 2004; Belzer & Autler, 2002; ITDP, 2020).

From a policymaking perspective, the study will generate practical, data-driven recommendations for improving zoning frameworks, development incentives, and planning policies in Tehran. These findings will be particularly relevant for urban planners, municipal authorities, and real estate stakeholders, providing guidance for optimizing land use around metro stations and advancing broader goals of urban sustainability, equity, and livability.

Ultimately, this research aims to enhance both academic and practical understanding of TOD implementation in Tehran. It will contribute to the body of knowledge on sustainable urban development in Global South cities while offering concrete, locally grounded strategies for transforming Tehran's metro station areas into vibrant, transit-supportive urban hubs.

1.6 Research Hypotheses

This research is grounded in three key hypotheses that aim to test the alignment of Tehran's urban development patterns with TOD principles, evaluate institutional barriers, and explore the potential benefits of improved urban design and infrastructure on public transit usage. These hypotheses serve as the foundation for analyzing spatial, regulatory, and socio-economic factors influencing TOD implementation in Tehran.

H1: The existing land use patterns around Tehran's metro stations do not align with TOD principles.

Transit-Oriented Development (TOD) emphasizes high-density, mixed-use, pedestrian-friendly environments centered around transit nodes. In successful TOD cities such as Tokyo, Copenhagen, and Singapore, metro stations serve as vibrant urban hubs, integrating residential, commercial, and public spaces within a short walking radius (400–800 meters). This model maximizes land efficiency, enhances transit accessibility, and reduces car dependency.

However, preliminary observations suggest that Tehran's metro station areas do not follow TOD guidelines. Many stations are surrounded by:

- Low-density or single-use developments, failing to attract commercial and residential investments.
- Disconnected pedestrian pathways, making it difficult for commuters to access transit facilities conveniently.
- Vacant or underutilized land, resulting in inefficient urban space utilization.
- Poor integration of transit with surrounding land uses, leading to reduced ridership potential and increased reliance on private vehicles.

This hypothesis will be tested by conducting spatial analyses of urban densities, land use distribution, and pedestrian connectivity near selected metro stations. By comparing Tehran's development patterns with international TOD benchmarks, this research aims to quantify the extent of misalignment and identify critical gaps requiring policy intervention.

H2: Institutional and regulatory barriers significantly hinder the effective implementation of TOD.

One of the primary reasons for the slow adoption of TOD in Tehran is the presence of institutional and regulatory challenges. A well-functioning TOD system requires strong governance, effective coordination between urban planning and transit authorities, and clear zoning policies that support transit-oriented growth (Cervero & Murakami, 2010; Suzuki et al., 2013).

However, Tehran's urban governance is characterized by:

- Fragmented decision-making among multiple municipal and national agencies, leading to inconsistencies in planning regulations.
- Restrictive zoning laws that do not encourage high-density, mixed-use developments near transit hubs.
- Lengthy bureaucratic approval processes, discouraging private-sector investment in TOD projects.
- Lack of financial incentives for developers, making TOD projects economically unfeasible.

This hypothesis will be evaluated through policy analysis, stakeholder interviews, and case studies of TOD planning frameworks in other global cities. The research will assess how institutional inefficiencies and outdated zoning codes prevent TOD realization and explore potential governance reforms to streamline the TOD approval and implementation process.

H3: Enhancing pedestrian infrastructure and mixed-use developments will increase public transit ridership.

A fundamental principle of TOD is that better-designed pedestrian environments and diverse land uses around transit stations increase metro ridership and reduce car dependency. Cities such as Stockholm, Hong Kong, and Portland have demonstrated that:

- Well-connected sidewalks, bike lanes, and pedestrian plazas encourage more people to use public transit.
- A mix of residential, commercial, and office spaces near transit stations creates a 24/7 urban environment, leading to higher transit demand.
- Reduced parking spaces and car-oriented infrastructure shift commuter preferences toward metro and bus systems.

In Tehran, many metro station areas suffer from poor pedestrian accessibility, lack of commercial activity, and automobile-dominated streets, discouraging potential transit users. To test this hypothesis, this research will:

- Conduct spatial and observational studies on pedestrian infrastructure and urban design quality near metro stations.
- Analyze ridership data before and after infrastructure improvements (if available) to assess the impact of pedestrian-friendly policies.
- Compare Tehran's station-area development patterns with successful TOD examples from international cities.

If supported, this hypothesis will reinforce the need for urban design improvements, zoning modifications, and financial incentives to attract mixed-use developments and create pedestrian-friendly environments around Tehran's metro network.

The three hypotheses proposed in this research will provide a structured framework for analyzing the key factors influencing TOD implementation in Tehran. By testing these hypotheses, this study will offer empirical evidence and policy recommendations that can help urban planners, policymakers, and transit authorities optimize land use strategies and enhance the role of metro stations as integrated urban hubs.

1.7 Methodology Overview

This study applies a mixed-methods research design that integrates GIS-based spatial analysis, fieldwork, policy review, and institutional assessment to explore the challenges and opportunities of implementing Transit-Oriented Development (TOD) in Tehran. The methodological framework is structured around the widely recognized 3D/5D model[2], focusing on five interrelated dimensions: Density, Diversity, Design, Destination Accessibility, and Distance to Transit. This conceptual model, validated in global TOD literature, enables a flexible and context-sensitive evaluation of urban conditions around Tehran's metro stations, while ensuring comparability with international practices.

To assess the spatial performance of metro station areas in alignment with TOD principles, the study incorporates a comprehensive set of spatial indicators, including population density, land use mix, floor area ratio (FAR), pedestrian infrastructure quality, and proximity to key services and transit nodes. These indicators are analyzed using GIS tools and organized in accordance with both the 3D/5D framework and Iran's National TOD Guideline.

[2] The 3D/5D model includes five dimensions originally introduced by Cervero and Ewing (2010) to analyze the relationship between the built environment and travel behavior.

Given the limitations of urban data availability in Iran, the study complements its GIS analysis with field-based validation techniques, including site visits, visual documentation, informal interviews with commuters and local stakeholders, and walkability assessments. This mixed-method approach enhances the credibility of the spatial findings by triangulating them with qualitative insights and real-world observations.

To evaluate the station areas systematically, the study employs a data-driven weighting method using the Entropy Technique, which assigns importance to indicators based on their variability across the dataset. This ensures that indicators with greater discriminative power play a stronger role in the overall assessment, supporting a more objective and robust evaluation process. Additionally, to identify typologies and patterns among station areas, the study utilizes K-Means clustering, enabling classification of metro stations into distinct categories based on their TOD-related characteristics.

Following the clustering phase, a stratified sampling method is applied to select case study stations for comparative analysis. From each cluster, the highest-ranked and lowest-ranked stations are selected to represent the performance extremes within that cluster. A comparative assessment is conducted both within clusters (top vs. bottom-ranked stations) and across clusters (top-performing vs. poorly-performing clusters). This comparative framework helps identify recurring weaknesses and strengths across the TOD spectrum and reveals key performance differentiators.

Based on these analyses, the weakest-performing station among all selected cases is identified as the critical intervention zone. A context-sensitive land use redesign strategy is then proposed for this station, grounded in TOD principles and informed by both local constraints and international best practices.

Furthermore, the study conducts a policy and institutional analysis by reviewing local master plans, zoning regulations, and TOD-related planning documents. This includes an assessment of the coordination between urban planning and transport sectors, regulatory barriers to high-density, mixed-use development, and institutional readiness for TOD implementation. Comparative insights from international best practices are used to propose policy reforms and governance improvements tailored to Tehran's urban context.

Overall, this methodology allows for a multi-scalar, multi-dimensional assessment of TOD in Tehran - bridging theoretical frameworks, empirical spatial data, and local institutional dynamics. The integrated use of spatial analysis, clustering techniques, stratified sampling, field observations, and policy review provides a holistic foundation for identifying weaknesses and opportunities in

Tehran's TOD landscape and for proposing context-appropriate land use strategies around metro stations.

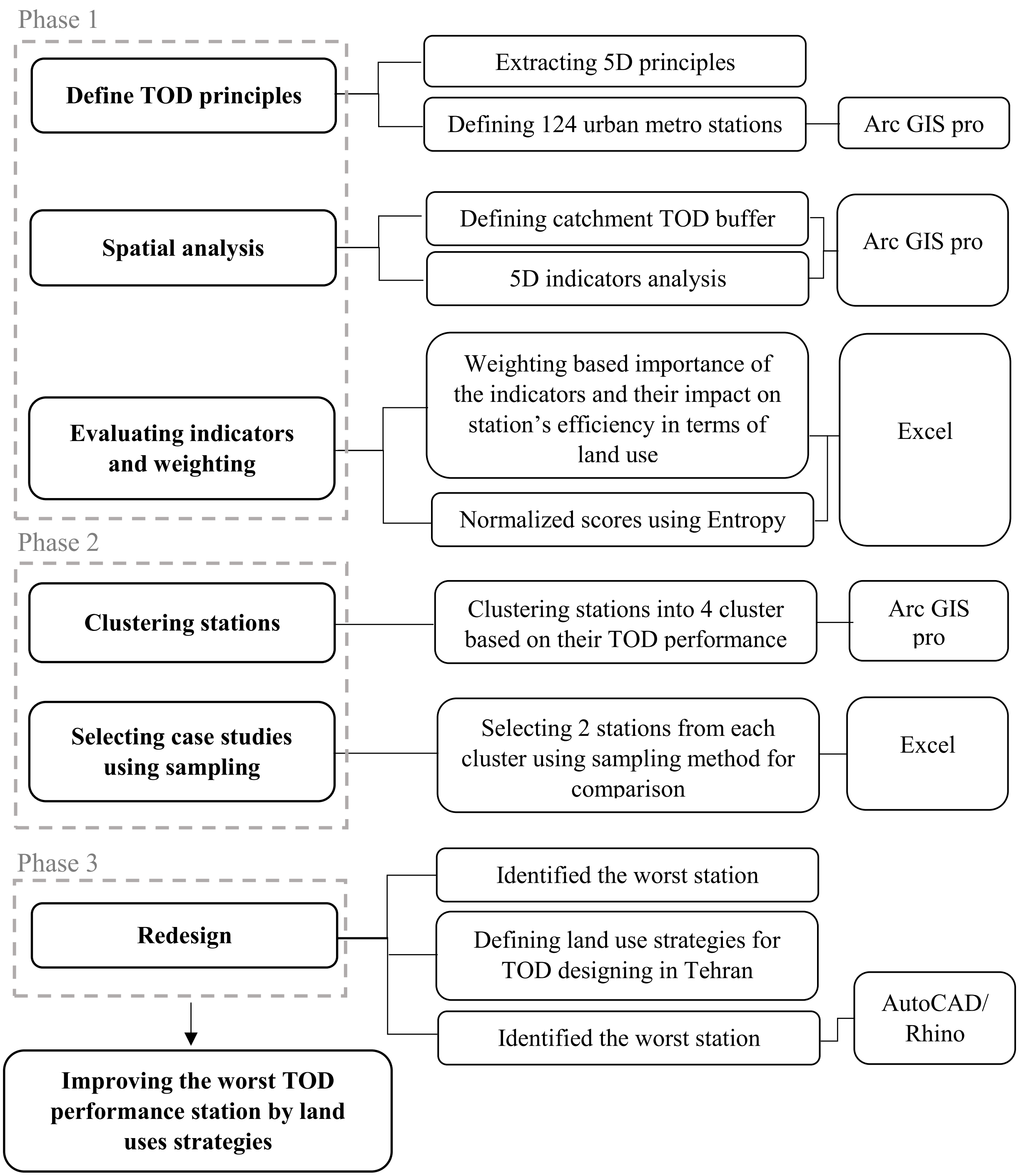


Figure 3 The flow chart of methodology by researcher

1.7.1 Data Collection and Analysis Methods

The core of the data analysis process is based on spatial evaluation using GIS to assess the land use structure, urban density, pedestrian accessibility, service coverage, and development intensity within the catchment areas of metro stations. Specific indicators include population density, land use mix, FAR, access to amenities, walkability, and connectivity to other transport modes. These indicators are calculated, normalized, and spatially visualized within a GIS environment.

Due to the limitations in access to high-quality urban data in Iran, manual validation methods are integrated into the process. These include on-site visits, photographic documentation, and informal interviews with residents and business owners, which help to enhance the accuracy of spatial analyses and ensure that findings are grounded in real-world urban conditions.

To determine the relative importance of each TOD indicator without relying on expert judgments, the study applies the Entropy Method, which assigns weights based on the statistical dispersion of indicator values (Naholo, A. P. 2021). Following the weighting, K-Means Clustering is used to group metro stations into homogeneous clusters, revealing patterns of underperformance or strength and supporting the selection of representative case studies for detailed exploration.

In parallel, a document-based policy analysis is conducted to evaluate institutional, legal, and planning-related factors influencing TOD implementation. The reviewed documents include Tehran's master plans, the National TOD Guideline, and relevant zoning and development regulations. This analysis identifies potential barriers and inconsistencies in policy frameworks and provides insight into areas for institutional reform and policy alignment.

1.7.2 Research Limitations and Challenges

Conducting urban research in Iran presents several significant challenges, particularly regarding data availability, regulatory constraints, and financial limitations. One of the major obstacles is the lack of updated, publicly available GIS datasets, as many urban planning databases are either restricted by the government or require expensive licensing fees. Additionally, Tehran's urban planning data is not standardized with global geospatial frameworks, making it difficult to compare TOD performance with international cities.

Sanctions and political restrictions have further complicated access to accurate satellite imagery and mapping services. Global platforms such as Google Earth, OpenStreetMap, and ESRI datasets are often outdated or intentionally blurred in Iranian cities, limiting researchers' ability to perform real-time urban analysis. Moreover, many municipal records and planning documents are not digitally archived or openly shared, requiring direct engagement with government offices and urban institutions - a process that is both bureaucratic and time-consuming.

Another key challenge is the high cost of urban data acquisition. Many planning datasets in Iran are not freely available, and obtaining official maps or statistical data often requires significant financial resources. Given the limited budget for urban research, this study prioritizes open-source datasets, alternative GIS tools, and collaborative data collection efforts with local experts and academic institutions.

Due to these constraints, this research will rely heavily on fieldwork and direct observations to compensate for missing or outdated data. Field surveys will include on-site assessments of metro station areas, pedestrian walkability studies, and informal interviews with commuters and local business owners. By combining spatial, policy, and community-based insights, the study ensures a comprehensive and context-specific assessment of TOD implementation in Tehran.

1.7.3 Justification for the Methodological Approach

This study adopts a comprehensive and context-sensitive methodological framework tailored to the unique urban complexities, institutional fragmentation, and data constraints characteristic of Tehran. To address these challenges, the research employs the 3D/5D analytical model - a well-established and flexible framework in TOD evaluation (Cervero & Ewing, 2010; Boarnet et al., 2017; Ewing & Tian, 2021). Unlike rigid standards such as the ITDP TOD Standard, which are often critiqued for limited applicability in Global South contexts (Suzuki et al., 2013; Guerra & Cervero, 2011), the 3D/5D model allows for adaptive indicator selection and metric calibration based on local socio-spatial conditions, making it particularly well-suited to Tehran’s urban context.

To enhance objectivity and reduce subjectivity in indicator weighting, the study applies the Entropy Method, a quantitative approach that determines the relative importance of each spatial indicator based on its variability across metro station areas (Zhao et al., 2020; Xu et al., 2022). This method is particularly effective in environments where institutional coordination is limited and consistent expert input is difficult to secure. Compared to expert-based approaches such as the Analytic Hierarchy Process (AHP), the Entropy Method provides a more data-driven and replicable weighting mechanism, especially valuable in data-rich but expertise-constrained urban settings.

For station classification, the study utilizes K-Means Clustering, an unsupervised machine learning algorithm that identifies latent spatial patterns and groups station areas based on similarities in

TOD-related indicators (Kandt & Batty, 2021; Zhou et al., 2023). This technique not only distinguishes high and low-performing station zones but also identifies transitional or hybrid areas that may benefit from targeted planning interventions. The clustering results provide a robust basis for spatial differentiation and targeted policy design.

Building on the clustering outcome, the research adopts a stratified sampling strategy to select representative case studies from each performance group. Specifically, it compares top and bottom-ranked stations within each cluster, enabling both intra-cluster and inter-cluster analysis. This comparative approach deepens the understanding of structural and contextual factors influencing TOD outcomes. The worst-performing station overall is then selected for detailed redesign, integrating TOD land use strategies based on both local needs and global precedents.

To ensure the validity of quantitative findings, the study incorporates a field-based validation phase involving site visits, walkability audits, and informal interviews with commuters and stakeholders. This is a critical step in Tehran, where informal development patterns, inconsistent regulatory enforcement, and limited digital datasets can obscure spatial realities (Mirmoghtadaee & Abdi, 2021). By comparing GIS-based metrics with on-the-ground conditions, this phase strengthens the reliability and applicability of the research outcomes.

In parallel, the study conducts a policy and institutional review, examining Tehran's master plans, zoning codes, and the National TOD Guideline (2020). This component assesses the alignment between land use and transport planning, identifies regulatory bottlenecks, and evaluates institutional readiness for integrated TOD implementation. The insights derived from this analysis inform recommendations that are not only spatially sound but also institutionally feasible and politically actionable.

In summary, the methodological approach adopted in this study reflects the current trajectory of urban planning scholarship, which emphasizes integrated, evidence-based, and place-specific strategies for sustainable urban transformation (UN-Habitat, 2023; Bertolini, 2022). By combining geospatial modeling, objective indicator weighting, machine learning classification, field validation, and institutional analysis, the research contributes a replicable and adaptable TOD assessment framework - designed to support urban policy innovation in Tehran and transferable to other Global South cities facing similar challenges.

1.8 Structure of the Thesis

This thesis is structured into four comprehensive parts that collectively explore the challenges, potentials, and implementation strategies of Transit-Oriented Development (TOD) in Tehran, with a particular focus on land use around metro stations. The structure follows a logical progression - from theoretical exploration to empirical spatial analysis, and finally, to design interventions and policy recommendations - ensuring that the research builds a holistic understanding of TOD within the specific context of Tehran.

Part I: Theoretical Foundations of TOD lays the conceptual groundwork for the study. It begins with Chapter 1, which introduces the background and significance of the research topic, articulates the research problem, outlines the main objectives, poses the central research questions and hypotheses, and provides an overview of the methodology. This chapter also explains the academic and practical relevance of evaluating TOD in Tehran. Chapter 2 presents an in-depth literature review and theoretical framework. It begins by outlining the global evolution of TOD, then explores its conceptual model (3D/5D framework), before delving into the integration of land use and transportation systems, global best practices, and the socio-political and urban challenges of implementing TOD. The chapter concludes by reviewing previous research on TOD in Tehran, identifying key knowledge gaps that this thesis aims to address.

Part II: Methodology and Spatial Analysis details the methodological approach adopted in this study. Chapter 3 defines the study area, explaining why Tehran was selected as a case study based on its population size, urban complexity, environmental challenges, and underperforming yet expansive metro system. The chapter also describes the research methods, including spatial data collection, indicator selection, and justification for the use of GIS-based tools. Chapter 4 presents the core spatial analysis, using the 3D/5D framework to evaluate TOD indicators across 124 metro stations. Through visualization techniques such as heatmaps and hotspot analysis, the study identifies spatial disparities in TOD performance. It also employs clustering and scoring methods to classify stations into categories such as high-potential, moderate, and underperforming. From this analysis, eight representative stations are selected for detailed case study exploration.

Part III: Case Studies Spatial Interpretation and Design Proposals applies the spatial findings to real-world urban contexts, focusing on the design and planning aspects of TOD at the station level. Chapter 5 provides a detailed analysis of the eight selected metro stations, comparing their functional, physical, and spatial characteristics. This comparative assessment uncovers the contextual factors that shape TOD performance in different urban zones of Tehran. Chapter 6 shifts the focus to design-based interventions, targeting the lowest-performing station identified in the preceding chapter. It introduces a series of spatial and land use strategies intended to enhance pedestrian accessibility, increase land use diversity, and improve the quality of the public realm surrounding each station. The design proposals are structured around the Place–Function–Design framework, ensuring that interventions respond to both systemic land-use challenges and the need for adaptable, inclusive urban environments. Each proposal is evaluated against TOD performance criteria and locally relevant planning objectives to ensure feasibility, policy alignment, and spatial effectiveness.

Part IV: Conclusion and Policy Recommendations synthesizes the research findings and translates them into actionable policy guidance. Chapter 7 summarizes the major conclusions drawn from the study, revisits the research questions and hypotheses, and outlines key policy and planning recommendations to enhance TOD implementation in Tehran. It introduces a framework for future TOD development that emphasizes integrated governance, regulatory reform, financial mechanisms, and participatory planning. The chapter concludes with a set of suggestions for future research, particularly on TOD monitoring, stakeholder engagement, and comparative studies across other cities in the region.

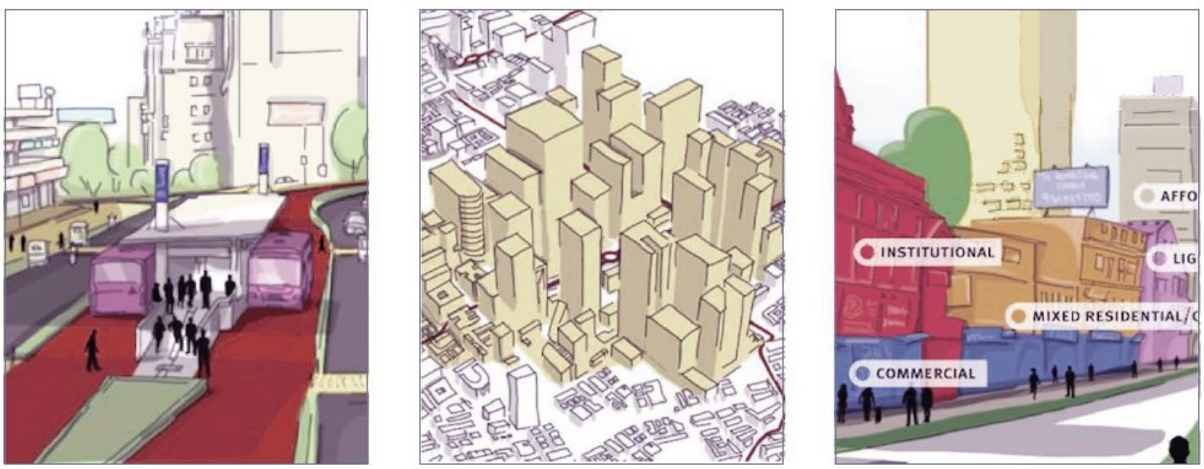
Overall, this thesis offers a comprehensive evaluation of TOD in Tehran by combining conceptual analysis, spatial assessment, urban design, and policy insights. The structure ensures that the research not only contributes to academic discourse but also offers practical strategies for urban transformation in Tehran and similar cities facing complex development challenges.

Chapter 2
Literature Review

2.1 Overview of Transit-Oriented Development (TOD)

Transit-Oriented Development (TOD) has emerged as a transformative and integrative planning model that seeks to address the interrelated urban challenges of traffic congestion, spatial fragmentation, environmental degradation, and socio-economic inequality. First introduced by Peter Calthorpe in the early 1990s, TOD advocates for the creation of high-density, mixed-use, and walkable neighborhoods centered around high-capacity public transportation systems such as metro, BRT, and commuter rail (Calthorpe, 1993). Unlike conventional car-oriented urban development, which leads to sprawl and inefficient infrastructure use, TOD emphasizes compact growth, pedestrian accessibility, and transit connectivity as foundational elements of urban sustainability (Suzuki et al., 2015).

Transit – Oriented Development



TRANSIT
Public transportation site including airport, railway station, metro station, bus station etc.

ORIENTED
Center with a radius of 400-800m (5-10 minutes walking distance)

DEVELOPMENT
Mixed use for work, business, residence, education and culture.

Figure 4 Core Components of Transit-Oriented Development (TOD)
Source: https://www.itdp.org/2013/11/13/transport-oriented-development-poster/

The fundamental goal of TOD is to encourage a shift from private vehicle use to more sustainable modes of transport by integrating land use and transportation planning. This is operationalized by concentrating residential, commercial, institutional, and recreational land uses within a comfortable walking radius, typically 400 to 800 meters (~2,000 foot), of a transit station (Bertolini et al., 2012). TOD prioritizes non-motorized transport modes such as walking and cycling, improves access to public services, reduces travel times and emissions, and supports healthier lifestyles. Furthermore, by fostering active street life, public space vibrancy, and economic clustering around transit nodes, TOD contributes to social interaction, urban vitality, and long-term resilience (Guerra & Cervero, 2011; Suzuki et al., 2015).

TOD plays a vital role in supporting the United Nations' Sustainable Development Goals (particularly SDG 11) and the New Urban Agenda, which advocate for inclusive, compact, connected, and resilient cities (UN-Habitat, 2016). Historically, early forms of TOD appeared in tram-based cities like Madrid's Ciudad Lineal and American streetcar suburbs. With the rise of automobile ownership post-1960s, car-oriented suburban development became dominant, often characterized by spatial segregation and limited public transport access. However, cities like Copenhagen and Stockholm deviated from this trend by channeling urban growth along rail corridors and implementing policies that promoted functional mix and proximity to transit (Knowles, 2012; Cervero, 1995).

Numerous cities around the world have adopted TOD-related strategies. For example, Singapore's land-use plans supported transit-accessible new towns (Richmond, 2008), while Tokyo's private rail companies developed commercial centers around terminal stations to generate passenger activity beyond peak commuting times (Chorus, 2009). Curitiba is a notable example of linear TOD planning along Bus Rapid Transit (BRT) corridors (Lindau et al., 2010).

TOD has also proven effective in reducing car dependency through policies such as parking restrictions, public transport expansion, land-use limitation, and inner-city revitalization, as seen in cities like Freiburg, Toronto, Portland, Vancouver, and Zurich (Newman & Kenworthy, 1996). In essence, TOD can be broadly described as the coordination of urban development around a public transport network (Hickman & Hall, 2008).

Generally speaking, one could define the idea of TOD as "careful coordination of urban structure around the public transport network" (Hickman and Hall, 2008). "TOD can be described as land-use and transportation planning that makes cycling, walking, and transit use convenient and desirable, and that maximizes the efficiency of existing public transit services by focusing development around public stations, stops, and exchanges," Thomas and Bertolini, 2017 write in more thorough definitions. Unlike these definitions, which underline the main relevance of transit for local neighborhoods, TAD (transit-adjacent development) is defined as a development which "lacks any functional connectivity to transit, either in terms of land-use composition, means of station access, or site design" (TCRP, 2002). Apart from that, some definitions underline the regional relevance of TOD by stating it as "an approach to station area projects which reaches further than single-locations, and aims at the re-centering of entire urban regions around transport by rail and away from the car" (Bertolini et al. 2012). If compact and dense developments were not properly integrated into a larger regional transport network, Ewing and Cervero (2001) claim they would have only minor impact on travel behavior. Underlying these theoretical ideas is the presumption that one can control travel demand by precisely planning and accounting for the effects of spatial organization and land-use on people's behavior and choices.

The next section introduces the theoretical and analytical frameworks used to operationalize TOD in this study.

2.2 Conceptual Framework of Transit-Oriented Development (TOD)

The conceptualization of Transit-Oriented Development (TOD) has evolved through various global planning frameworks that aim to integrate land use and transportation in ways that promote sustainable, efficient, and inclusive urban growth. Several standardized frameworks have emerged over the past decades to define, measure, and implement TOD principles in diverse contexts. Among these, two prominent global models are the ITDP TOD Standard and the 3D/5D framework developed by urban scholars such as Cervero and Ewing.

The ITDP TOD Standard (2017) based in New York City -United States, developed by the Institute for Transportation and Development Policy, is one of the most widely used evaluation tools for TOD around the world. It structures TOD performance around eight core principles - Walk, Cycle, Connect, Transit, Mix, Densify, Compact, and Shift - and translates them into 24 specific indicators with a comprehensive 100-point scoring system. This model is designed to promote high-quality, human-centered transit environments by focusing on infrastructure design, urban form, accessibility, and land use intensity (ITDP, 2017). The ITDP Standard is especially useful for assessing the TOD quality of newly planned or redeveloped urban areas and has been applied in multiple global cities as a benchmarking tool.

Figure 5 The eight principles for transport in urban life work together to create inclusive and sustainable communities and cities. ITDP.

However, despite its global utility, the ITDP model faces significant limitations when applied in developing country contexts like Tehran. It assumes strong institutional capacities, detailed urban data availability, enforceable zoning regulations, and well-developed pedestrian and cycling networks - all of which are either weak or inconsistent in many parts of Tehran. The model's fixed scoring structure is often too rigid to accommodate the complex realities of informal development, governance fragmentation, and socio-cultural preferences present in Iranian cities (Mirmoghtadaee & Abdi, 2021; Kamani-Fard & Jafari, 2021). Therefore, while ITDP principles are conceptually relevant, their quantitative scoring system may not be applicable in its original form.

To address such limitations, scholars have proposed more flexible conceptual approaches, among which the 3D/5D framework is widely regarded as both analytically sound and adaptable to different planning contexts. Initially introduced as the 3Ds - Density, Diversity, and Design - the model was expanded to include Destination Accessibility and Distance to Transit (Ewing & Cervero, 2010). These dimensions focus on how urban form influences travel behavior, allowing planners to analyze the built environment's impact on public transit use:

- **Density**: The objective of density is to increase the resident population by offering more housing and a higher FAR in the transit station nearby. The larger number of residents can have access easily to transportation and social housing. As a result, the increase in residents can increase the public transport users and strengthen the local labor force. Meanwhile, efficient transit can decrease the possession of private automobiles which can benefit the environment and reduce road accidents.
- **Diversity**: Diversity means the mixed land uses and the variety of destinations in the transit station. It plays an essential part in stimulating the local economy and providing services. Furthermore, the destinations like offices and social services concentrated in the transit area can reinforce the connection between the neighborhood and the whole city. Thus, the diversity in land use can be beneficial to prevent local degradation. Through the examinations, the researchers established a standard configuration for the mixed land-use, which made up four categories: residential occupies 50%-80%, commercial 10%-40%, and services and public space 10%-15%. This arrangement has been shown to create a self-sustaining community, where all destinations are reachable within a fifteen-minute radius (Kristianto et al., 2020).
- **Design**: Design refers to constructing safe pedestrian road networks and improving the building environment. TOD aims to minimize automobile usage and promote public

transportation such as transit, pedestrian, and cycling. Therefore, the design of suitable transport infrastructure is one of the major goals. Furthermore, the design of building and land use zoning can help capture the land value and improve the efficiency of transit. In 2008, Cervero and Murakami introduced the 5D principle as an extension of the 3D principle.

- **Destination Accessibility**: Measures access to jobs, services, and key activity centers.
- **Distance to Transit**: Evaluates ease of physical access to public transport stations.

This framework is particularly valuable in data-constrained environments, as it allows for the use of locally available indicators and supports customized weighting schemes depending on planning priorities. It has been validated in numerous empirical studies worldwide, including in emerging economies where TOD conditions differ from Western urban models (Guerra & Cervero, 2011).

Feature / Criteria	ITDP TOD Standard	3D/5D Framework
Origin	Institute for Transportation and Development Policy (2017)	Academic (Cervero, Ewing, 2010)
Structure	8 Principles, 24 indicators, 100-point score	3D: Density, Diversity, Design → 5D adds Destination Accessibility, Distance to Transit
Flexibility	Rigid, fixed-point scoring	Flexible, customizable indicators
Data Requirements	Detailed design-based spatial data	Can use aggregated and spatial data
Application Context	Best suited to new developments in high-capacity cities	Widely used in both developed and developing countries
Relevance to Iran	Limited (due to rigid scoring and institutional assumptions)	High (adaptable to Tehran’s local realities)

Table 2 Comparison of TOD Frameworks: ITDP Standard vs. 3D/5D Model
Source: made by author

Based on this global review, this study proposes a hybrid conceptual framework tailored to Tehran’s urban planning and institutional realities. While the ITDP principles (Walk, Cycle, Connect, etc.) are retained as qualitative goals and thematic categories, the analytical structure of the framework is based on the 3D/5D model. This allows for a more flexible and localized TOD evaluation, using measurable spatial indicators derived from GIS data, Iranian planning guidelines, and field observations.

The hybrid model in this research includes indicators such as:

- **Population and building density** (FAR and per hectare density),
- **Land use mix** (Shannon and Entropy indices),
- **Pedestrian accessibility and connectivity**,
- **Proximity to public services and facilities**, and
- **Access to multi-modal transit (metro, bus, BRT, taxi)**.

Additionally, based on findings from Iranian sources, the study adapts the standard TOD station catchment area (400–800 meters) by introducing a 500-meter buffer for dense urban contexts, where accessibility patterns differ due to fine-grained urban morphology and higher land use intensity (Shirzadi & Rafieian, 2023).

To assess the relative importance of these indicators, the study applies a dual weighting methodology:

1. **AHP (Analytic Hierarchy Process)** – capturing expert-based prioritization;
2. **Entropy Method** – incorporating data-driven variability across spatial datasets.

This integrated conceptual framework aligns with Iran's National TOD Guideline (2020), which emphasizes localized evaluation tools, institutional integration, and practical planning instruments for TOD implementation. By synthesizing international frameworks with national policies and urban realities, the study provides a comprehensive and adaptable model for TOD assessment in Tehran and similar contexts.

2.3 Benefits and Challenges of TOD in Global Contexts

Transit-Oriented Development (TOD) has emerged as a globally recognized strategy for promoting sustainable, inclusive, and efficient urban development. In cities across the world, TOD has demonstrated a range of benefits that span economic, social, environmental and Technical-Innovation dimensions.

1. Economic Benefits

TOD enhances land use efficiency and stimulates economic growth by concentrating development near transit hubs. The high foot traffic around these areas boosts commercial activity, supports local businesses, and reduces congestion by encouraging public transport use. This model shifts commercial development from being optional to essential in urban centers, contributing to long-term sustainability and urban vibrancy.

2. Social Benefits

TOD improves residents' quality of life by offering better access to public transportation, reducing travel time and costs. It supports healthier lifestyles through lower pollution levels and more green spaces. By integrating housing, commerce, and community services, TOD fosters social cohesion, multicultural interaction, and inclusivity. High-density planning also allows for more affordable housing options without compromising living comfort.

3. Environmental Benefits

By reducing dependence on private vehicles, TOD helps decrease air and noise pollution, easing traffic congestion and enhancing the urban environment. Mixed-use, walkable neighborhoods reduce the ecological footprint of cities while promoting sustainable, vibrant communities. These features contribute to improved public health and environmental resilience.

4. Technical and Innovation Advantages

TOD integrates land use with modern transport systems to reduce urban congestion and encourage green mobility. It supports the development of polycentric urban forms and improves city functionality. In regions like China, TOD aligns with advanced infrastructure systems - high-speed rail, highways, ports, and airports - to enhance national connectivity and competitiveness. Efficient transport networks reduce intra-city pressure, improve regional equity, and support balanced economic growth.

TOD offers a holistic solution to urban challenges by linking economic efficiency, environmental sustainability, and social inclusion. Its core value lies in creating compact, accessible, and well-connected urban spaces that improve quality of life while supporting long-term urban resilience (Yuan W., 2025).

Despite these advantages, the implementation of TOD faces several challenges, particularly in cities with entrenched car-centric planning systems. One of the major barriers is the high cost of infrastructure investment, including transit construction, public space upgrades, and redevelopment of underutilized land parcels. Institutional fragmentation also poses a serious challenge; effective TOD requires coordination between multiple agencies - transport, housing, urban planning, and finance - which is often lacking in both developed and developing cities. Moreover, TOD projects can trigger land speculation and gentrification, leading to the displacement of vulnerable populations and rising housing costs near transit zones. There is also public resistance to densification, especially in societies accustomed to low-density, car-oriented

lifestyles. Efforts to implement TOD often encounter opposition from residents concerned about increased congestion, changing neighborhood character, or property devaluation (Bertolini et al., 2012; Talen, 2013; Staricco, L., & Vitale Brovarone, E. 2018; Cervero, R., & Dai, D. 2014).
These global challenges are particularly evident in the context of Tehran, where several structural and socio-cultural barriers have limited the successful implementation of TOD principles While TOD is recognized as a strategy for achieving sustainable urban development, integrating land use and transportation planning remains a complex task, particularly in contexts where urban policies have historically prioritized car-oriented growth. This section explores the primary obstacles that hinder the successful implementation of TOD, drawing from global and regional experiences.

- **Institutional and Governance Barriers**

A recurring obstacle in TOD implementation worldwide is institutional fragmentation. Successful TOD requires the seamless coordination of transportation, land use, housing, environmental planning, and finance - yet in many cities, these functions are spread across multiple disconnected agencies. In the United States, for instance, fragmented jurisdictions between municipal governments, regional planning bodies, and transit authorities have hindered coordinated land use decisions around transit hubs (Guerra & Cervero, 2011). Similarly, in India, overlapping responsibilities between urban development authorities and metro rail corporations have created delays and inconsistencies in TOD execution (Suzuki et al., 2013).
The absence of clear, enforceable, and supportive regulatory frameworks is another global issue. In many cities across Latin America and Southeast Asia, zoning regulations remain outdated or rigid, prohibiting the mixed-use, higher-density developments needed to support TOD. For example, in Bangkok, rigid land use controls and weak enforcement mechanisms have resulted in scattered high-rise development with little functional integration with transit systems (World Bank, 2020). This is not dissimilar to the Iranian context, where zoning laws often fail to align with TOD objectives (Motieyan & Mesgari, 2017).

- **Urban and Infrastructure Limitations**

Physical and infrastructural limitations significantly affect TOD implementation across both developed and developing urban contexts.
A major issue is the lack of high-quality pedestrian and cycling infrastructure that links transit stations with surrounding neighborhoods - a gap often referred to as the “first-mile/last-mile” problem. For instance, in Johannesburg, South Africa, the Gautrain TOD initiative has been

constrained by poor last-mile connectivity in nearby townships, reinforcing reliance on private automobiles even in close proximity to rail corridors (Salon & Aligula, 2012; Wood, 2015). Studies show that safety, convenience, and walkability in the final segment of a trip are decisive factors in commuters' willingness to use transit services (Venter, Jennings, Hidalgo, & Valenzuela, 2018).

In rapidly urbanizing cities of the Global South, including Nairobi, Lagos, and Dhaka, fragmented land ownership, informal settlements, and unregulated urban growth pose additional challenges. In these contexts, transit-adjacent land is frequently occupied by informal housing or small-scale commercial activity, complicating coordinated redevelopment and land assembly (Suzuki, Cervero, & Iuchi, 2013; Rahman, 2022). For example, in Dhaka, weak enforcement of planning regulations and narrow, unplanned streets restrict the integration of TOD principles and often require substantial resettlement to make space for upgraded infrastructure (Ahmed & Bramley, 2015).

Even in older urban centers in Europe and parts of the Middle East, retrofitting TOD into historically dense and constrained environments presents unique difficulties. Cities like Barcelona, Paris, and Istanbul face land scarcity and heritage preservation concerns that limit large-scale redevelopment. In these cases, TOD implementation often depends on incremental strategies such as pedestrianization, fine-grained mixed-use zoning, and targeted infill development rather than comprehensive spatial restructuring (Bertolini, 2022; UN-Habitat, 2023).

- **Financial and Market Constraints**

The financial viability of TOD remains a major hurdle worldwide. TOD requires upfront capital for transit infrastructure, land acquisition, and public realm improvements - resources that are often scarce in cities with limited municipal budgets. In many North American cities, for example, TOD implementation is constrained by budget cuts and political reluctance to fund public transportation through tax increases (Cervero et al., 2017).

In Global South contexts, reliance on central government subsidies and donor financing is common, but insufficient for sustained TOD efforts. Lack of institutional experience with financial instruments such as land value capture (LVC), tax increment financing (TIF), or development impact fees weakens the fiscal basis for TOD. Even when these tools are introduced, legal ambiguity and administrative complexity often limit their effectiveness. For instance, although

Colombia pioneered LVC for transit infrastructure in Bogotá and Medellín, replicating this success in other cities has proven difficult due to governance and market differences (Suzuki et al., 2015). Furthermore, speculative landholding near transit corridors can prevent timely and affordable TOD implementation. In cities like Jakarta and Manila, developers often acquire land in anticipation of transit expansion but do not build until prices peak, resulting in land banking and low-density sprawl near expensive infrastructure (Aalto University, 2019).

- **Socio-Economic and Equity Concerns**

One of the most globally debated challenges of TOD is the risk of gentrification and displacement. As transit accessibility increases, land and housing values rise, potentially displacing low-income residents who rely most on public transit. This phenomenon has been observed in cities such as San Francisco, London, and Vancouver (Zuk et al., 2017). Without affordable housing mandates, rent control policies, or anti-displacement measures, TOD can exacerbate social inequality rather than reduce it.

In many developing cities, TOD implementation also collides with entrenched poverty and informal housing. Without parallel investments in social housing, subsidies, and legal protections, the poorest residents are often excluded from TOD zones and pushed to the urban periphery - undermining one of TOD's central goals: equitable access to opportunities (UN-Habitat, 2023).

- **Cultural and Behavioral Resistance**

Finally, socio-cultural resistance to TOD remains a formidable challenge. In many car-dependent societies - whether in North America, the Middle East, or parts of Asia - low-density, automobile-oriented living is considered a status symbol, particularly among middle- and upper-class households. Public preference for detached housing, car ownership, and suburban lifestyles can hinder public acceptance of compact, vertical, and mixed-use development.

For instance, in Australia, despite supportive TOD policies, many suburban communities have pushed back against densification due to perceived impacts on traffic, parking, and neighborhood character (Legacy et al., 2014). Likewise, in several Iranian cities, public resistance to high-rise development and pedestrianization remains an obstacle to widespread TOD adoption (Mirmoghtadaee, 2020).

Transit-Oriented Development holds substantial promise for fostering sustainable, inclusive, and connected urban environments. However, its global implementation is constrained by a complex set of institutional, infrastructural, financial, socio-cultural, and equity-related barriers. While these challenges manifest differently across regions and income levels, they share common roots in fragmented governance, limited capacity for coordinated investment, and insufficient public buy-in.

Addressing these challenges requires comprehensive policy alignment, long-term financial planning, and inclusive governance models. For countries like Iran, learning from the diverse global experiences - both successes and setbacks - can inform more context-sensitive and adaptable TOD strategies that balance urban growth with social equity and environmental responsibility.

2.4. TOD and Land Use Integration

Effective land use integration is a fundamental pillar of Transit-Oriented Development (TOD), ensuring that transit infrastructure is reinforced by supportive zoning policies, urban design strategies, and development frameworks. Land use planning dictates the spatial structure of cities - where people live, work, shop, and socialize - and thus directly influences travel behavior and transport system efficiency. In a TOD context, land use planning is reoriented to concentrate activities within walkable distances of public transit, especially high-capacity systems such as metro or BRT, while simultaneously promoting compactness, accessibility, and vibrancy in urban environments (Cervero & Kockelman, 1997; Suzuki et al., 2015).

One of the central tenets of TOD land use integration is mixed-use development, which co-locates residential, commercial, and institutional functions within the same urban fabric. Mixed-use development minimizes the need for long-distance commuting, fosters local economic vitality, and supports “24-hour neighborhoods” where activity is sustained throughout the day. Research has consistently shown that areas with higher degrees of land use mix are associated with greater transit ridership, lower car ownership rates, and increased pedestrian movement (Ewing & Cervero, 2010; Zarrabi & Motealleh, 2021). Merging the rail-transit system with surrounding land use can solve transportation and urban development issues in a comprehensive way (Huang et al., 2021). Back and forth, TOD and land are usually integrated to encourage public and non-motorized transportation modes and alleviate the pollution caused by car dependency (Abdi, 2021). According to Berawi et al. (2019), the suitable proportions for land planning in TOD areas are designated as 46% for residential purposes, 18% for offices, 23-26% for commercials such as hotels and retail, and 12-13% for other land use type because the proportion will allow more properties to be developed in one area. The essential parts of the development, such as compactness and mixed-used activities, will influence the allocation or distribution of land use within the transit-oriented development radius. TOD will organize settlements around transit nodes as centers of urban life (Ibraeva et al.,2020) since it involves intense, mixed development around transit nodes (Yang & Pojani, 2017) and allows a mix of residential and commercial (Kamal,2019). In the Iranian context, however, many metro station areas remain dominated by mono-functional land use, limiting the potential for synergy between transit and urban form (Mirmoghtadaee & Abdi, 2021).

High-density development is another critical component of TOD land use integration. Density - both in terms of population and built floor area - provides the necessary threshold to support frequent and efficient transit service. Higher densities generate more riders, justify infrastructure investment, and reduce the cost per passenger trip. Empirical studies show a strong correlation between increased residential or employment density and higher transit mode shares (Cervero & Guerra, 2011). Importantly, density in TOD is not simply about vertical growth but must be combined with mixed uses and human-scale design to ensure livability and pedestrian comfort.

In successful TOD examples globally, the integration of public spaces and pedestrian-oriented design plays a transformative role. Well-designed public spaces - such as plazas, green corridors, pocket parks, and transit plazas - serve as communal gathering areas and enhance the urban experience around transit stations. Complementary pedestrian and cycling infrastructure - wide sidewalks, shaded walkways, traffic-calming streets, and bike lanes - enable safe and attractive non-motorized access to transit. These elements not only reduce car dependence but also promote equity by improving mobility for children, elderly, and low-income populations who may not have access to private vehicles (Suzuki et al., 2015; ITDP, 2017).

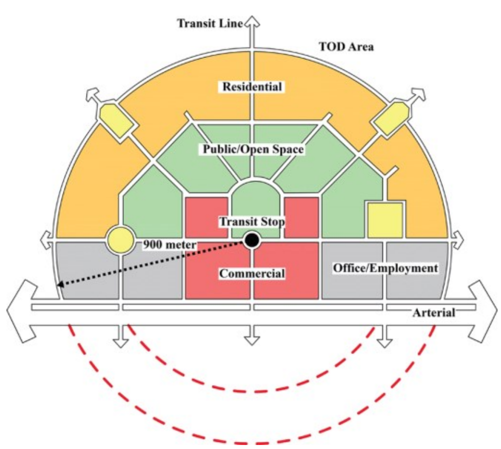


Figure 6 Land Use Allocation in TOD: International Best Practice Ratios
Source: Huang et al. (2021)

A significant barrier to TOD success, especially in many developing cities, lies in outdated zoning regulations and inflexible land use codes. Traditional zoning practices often emphasize land use segregation, minimum parking requirements, and height limits that conflict with TOD goals. In contrast, cities like Portland (USA), Vancouver (Canada), and Curitiba (Brazil) have adopted form-based codes, overlay zones, and density bonuses that encourage transit-supportive development patterns (Talen, 2013; Bertolini et al., 2012). These regulatory innovations align building form and function with street design, public realm quality, and transit access, rather than rigid land use categories.

The National TOD Guideline of Iran (2020) recognizes these barriers and calls for coordinated reforms in zoning policy, institutional alignment, and financial incentives to promote compact, walkable, and mixed-use transit districts (Mirmoghtadaee & Abdi, 2021).

Thus, the integration of land use and transport within a TOD framework requires not only physical interventions but also regulatory innovation and institutional collaboration. Aligning zoning, design, and infrastructure around transit nodes is critical for creating sustainable and inclusive urban environments that support efficient public transport systems.

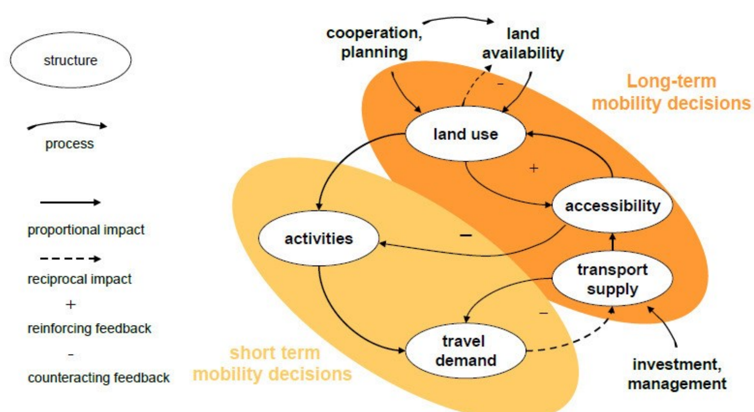


Figure 7 Feedback Loop Between Land Use and Transportation in TOD Framework
Source: (Farooq, A. et al., 2017)

The diagram illustrates the complex and dynamic relationship between land use and transportation systems, which is central to the concept of Transit-Oriented Development (TOD). It highlights how long-term decisions regarding land use, accessibility, and transport supply are deeply interconnected and jointly shape urban mobility patterns. In a TOD framework, well-coordinated land use planning increases accessibility to key destinations by concentrating population and activities near transit infrastructure. This, in turn, enhances the effectiveness and utilization of public transportation systems. As transport supply expands and becomes more reliable, it supports greater travel demand and encourages people to choose transit over private cars, especially when paired with pedestrian-friendly environments and mixed-use development. The diagram also shows how short-term mobility decisions (such as daily travel choices and activity patterns) are influenced by these structural elements and, over time, reinforce or alter the land use configuration. For example, increased accessibility can lead to higher demand for development around transit stations, fostering compact and vibrant urban nodes. This feedback loop is essential to TOD success: land use influences travel behavior, and travel behavior shapes future land use decisions. However, without coordinated planning and investment, this cycle can become fragmented, leading to urban sprawl and car dependency. Thus, effective TOD requires the integration of land use policies, transport planning, and accessibility strategies to ensure that development supports sustainable mobility, equitable access, and efficient urban growth.

2.4.1 Transport-Land Use Governance Models

The governance of urban transport and land use in Iran is marked by institutional fragmentation, financial constraints, and limited policy integration, all of which undermine the implementation of Transit-Oriented Development (TOD) principles. While municipalities are legally mandated to oversee urban affairs, including the execution of transport and land use plans, these responsibilities are often carried out in a siloed and uncoordinated manner (Shirzadi Babakan et al., 2018; Ramezani et al., 2023).

Although in theory Iranian urban planning systems encourage the alignment of transportation and land use policies, in practice the process is fragmented due to overlapping mandates of national ministries (such as MOI and MRUD), municipal bodies, and sector-specific organizations (Farhoodi et al., 2009; Abdi & Lamíquiz-Daudén, 2021). This multiplicity of actors often results in unclear roles, duplicated efforts, and policy conflicts that weaken inter-agency cooperation (Sorensen, 2018; Ramezani et al., 2023).

Municipalities still retain responsibility for localized initiatives, including traffic control, travel demand management, and vehicle inspections. However, urban transport departments frequently face severe financial limitations that restrict their ability to upgrade infrastructure, expand public transit fleets, or develop non-motorized transport (NMT) facilities such as bike racks and pedestrian corridors (World Bank, 2005; Mirmoghtadaee, 2016). These departments typically rely on central government transfers and have little independent revenue, which hampers their responsiveness to local needs.

The urban planning process is further constrained by rigid zoning laws and an approval structure involving multiple commissions, many of which derive revenue from land-use change fines. This has led to a regulatory cycle in which land-use decisions are driven by revenue-seeking behavior rather than long-term spatial quality or TOD principles (Pakzad, 2015; Shirzadi Babakan et al., 2018). Even when urban plans are outdated or flawed, they tend to be implemented without revision, reflecting an institutional resistance to adaptive planning (Ramezani et al., 2023).

Another critical barrier to TOD implementation is the disconnect between planned public uses and the actual landownership structure. Much of the land earmarked for public services is privately owned or institutionally controlled, making land assembly and development extremely difficult. The Mehr housing program [3] serves as a notable example, where top-down national decisions were implemented without regard to local planning frameworks, leading to increased car dependency and uncoordinated urban growth (Habibi & Dehghan Monshadi, 2015; Madanipour, 2006).

Local governments also face administrative limitations. They are often compelled to follow prescriptive national directives that do not account for local socio-spatial contexts, thereby weakening context-sensitive planning approaches (Vahidi Borji, 2017). Moreover, land use decisions can be heavily influenced by powerful non-governmental actors, including members of parliament, investors, and religious institutions, whose interests may not align with inclusive or sustainable urbanism (Sorensen, 2018; Abdi & Lamíquiz-Daudén, 2021).

Tan et al. (2014b) conceptualize such institutional and procedural challenges as "formal barriers" to TOD, highlighting the need for structural reforms that would allow for greater institutional flexibility, cross-sector collaboration, and decentralized authority. Alongside these, "informal barriers", such as socio-cultural norms, political patronage, and public skepticism, also shape planning outcomes and require innovative, learning-based approaches to overcome.

In sum, the transport–land use governance model in Iran is characterized by top-down decision-making, fragmented institutional roles, and limited inter-scalar coordination. These challenges pose significant obstacles to the implementation of TOD, which depends on spatial integration, participatory planning, and multi-level governance. Addressing these barriers will require both formal institutional reforms and informal capacity-building efforts aimed at fostering a more collaborative and adaptable planning culture.

[3] A national policy initiative known as the Mehr Housing Program was started in the 2000s with the goal of giving Iran's low-income citizens access to affordable housing.

2.5 Global Best Practices in TOD

Transit-Oriented Development (TOD) has been successfully implemented in numerous cities worldwide, offering valuable lessons in policy design, planning frameworks, land use integration, and stakeholder coordination. These international examples provide critical insights into how TOD principles can be adapted to support sustainable, inclusive, and efficient urban development. Examining best practices from globally recognized TOD cities such as Tokyo, Hong Kong, Singapore, Copenhagen, and Portland help identify transferable strategies and contextual differences that inform more effective TOD implementation in cities like Tehran.

One of the most notable examples is Tokyo, where TOD has been deeply embedded into the city's post-war urban development. High-density mixed-use development is tightly integrated with an extensive rail network, and private rail operators play a key role in urban land development. Transit companies own and manage land around stations, building residential, retail, and commercial projects that generate ridership and revenue. This model of rail + property development has ensured the financial sustainability of transit infrastructure and supported compact, vibrant urban centers (Cervero & Murakami, 2009).

In Hong Kong, a similar model is implemented through the Mass Transit Railway Corporation (MTR), which practices value capture financing - recouping transit investment costs through land development profits. This has allowed MTR to not only operate without government subsidies but also foster high-density, walkable environments surrounding stations. The city's vertical urban form, efficient land use policies, and pedestrian-focused planning have made it a global TOD benchmark (Suzuki et al., 2015).

Singapore integrates land use and transport planning through centralized governance and a comprehensive master plan. The Land Transport Authority and Urban Redevelopment Authority collaborate to align housing, transit, and economic development in a way that maximizes transit access and minimizes sprawl. Singapore's TOD success also stems from stringent car ownership controls and continuous investment in high-capacity mass transit systems (Phang, 2003).

In Copenhagen, TOD is shaped by the Finger Plan, which channels urban growth along radial transit corridors, leaving green wedges between them. This spatial model ensures that new development is compact and transit-oriented, while preserving open space. Copenhagen also prioritizes cycling as a key mode, integrating bike lanes with train stations and encouraging active mobility (Knowles, R. D. (2012).

Portland, Oregon, has implemented TOD through regional planning policies, urban growth boundaries, and form-based zoning. The city's focus on mixed-use zoning, pedestrian infrastructure, and transit-accessible housing has produced several TOD corridors that demonstrate increased transit ridership and walkability. Importantly, Portland has leveraged public-private partnerships and community engagement to promote equitable and inclusive TOD outcomes (Dittmar & Ohland, 2004).

Each of these cases illustrates the importance of policy alignment, institutional coordination, flexible zoning, and financial innovation in enabling TOD. While their institutional and economic contexts differ, they share common success factors: integrating land use and transit planning, leveraging land value through development incentives, providing high-quality pedestrian infrastructure, and ensuring long-term transit investment.

For Tehran, these examples underscore the need for a context-sensitive adaptation of TOD principles. While the financial models or governance structures may not be directly transferable, the core strategies - such as densification near transit, value capture tools, and mixed-use zoning - offer actionable pathways for reform. By learning from these global experiences, Tehran can better align its metro system with land use priorities to foster a more efficient, equitable, and sustainable urban future.

2.6 TOD and Land Use Strategies in Iran

Tehran's metro system, one of the largest in the Middle East, serves as the backbone of the city's public transportation network. With over 250 kilometers of track and more than 120 stations, the metro carries approximately 2 million passengers daily (Tehran Metro Report, 2023). Despite this extensive network, land use planning around metro stations has not fully embraced TOD principles. Instead of compact, high-density developments, many areas surrounding metro stations remain underutilized, dominated by low-rise buildings, surface parking lots, and disconnected urban spaces.

- **Existing Land Use Policies and Zoning Regulations**

Iran's land use planning (LUP) system is grounded in a historical legacy of centralized and blueprint-oriented planning, particularly influenced by Western models during the Pahlavi era (Pakzad, 2015). Over the last five decades, comprehensive master plans and detailed zoning plans have formed the backbone of urban development. These plans rely on rigid per capita standards and fixed land use allocations, leading to inflexibility in adapting to changing social, environmental, and transportation needs (Farhoodi et al., 2009).

Master plans outline the strategic distribution of land uses at the citywide level, while detailed plans specify zoning codes and development guidelines down to individual parcels. These are legally binding documents approved by the Supreme Council of Urban Planning and Architecture and implemented under the oversight of the Ministry of Roads and Urban Development and municipalities (Ramezani et al., 2023). However, the system suffers from fragmentation, where overlapping mandates between governmental agencies hinder effective coordination.

Iran's LUP system operates largely in a top-down fashion, with minimal integration of informal norms, public participation, or contextual values. The planning framework has historically neglected participatory mechanisms and continues to prioritize technocratic over inclusive approaches (Vahidi Borji, 2017). This has resulted in a disconnect between formal zoning laws and actual land use practices, especially in rapidly urbanizing or informal settlement areas.

Critically, this rigid and static zoning system presents a significant obstacle to the integration of land use and transport - one of the foundational principles of TOD. Zoning laws in Iran often prescribe single-use zones that separate residential, commercial, and public functions. This undermines the mixed-use character required for TOD, where residential, retail, office, and public uses should be co-located near transit hubs (Abdi, 2021). Furthermore, density regulations are typically generalized at the city level and do not support the strategic densification around transit stations. For instance, the same floor area ratio (FAR) or building height restrictions may apply in both peripheral and transit-accessible areas, preventing the necessary intensification that TOD demands (Ramezani et al., 2023).

Another challenge lies in the bureaucratic and time-consuming process required to change land use designations. Multiple layers of review and approval, often involving commissions that are incentivized by the collection of change-of-use fines, create a cycle where even poorly planned land use arrangements remain unaltered. This discourages municipalities from proactively aligning zoning with evolving public transport investments (Abdi, 2021).

Moreover, the absence of localized or flexible zoning overlays near metro stations - common in international TOD models - means there are no institutional mechanisms in place to promote walkability, mixed-use development, or transit-supportive densities in Iranian cities. As a result, urban expansion continues in a fragmented, car-dependent manner, even in areas theoretically suited for TOD (Ramezani et al., 2023).

In addition to formal constraints, informal practices, such as political lobbying and land speculation, further distort the intended zoning outcomes. Influential individuals, including investors or local political representatives, can influence zoning decisions for personal or affiliated interests, weakening the alignment between planning regulations and sustainable development goals (Sorensen, 2018; Abdi, 2021).

Overall, the current land use and zoning framework in Iran lacks the flexibility, integration, and spatial logic needed to support Transit-Oriented Development. Bridging this gap will require institutional reforms, dynamic zoning tools, and policy shifts that prioritize multimodal accessibility, density, and functional diversity around transit infrastructure.

Proposed Conceptual Model for Improving Iran's LUP

To address the institutional and spatial inefficiencies of Iran's current land use planning system, Ramezani et al. (2023) propose a conceptual model based on the Institutional Analysis and Development (IAD) Framework. This model emphasizes the interaction between formal rules, informal norms, and planning practices to improve the responsiveness and integration of LUP in Iran. Key components include:

- **Action Arena**: The central space where various actors including municipalities, ministries, private developers, and the public interact, negotiate, and influence land use decisions.
- **Rules-in-Use**: This layer recognizes both formal institutions (e.g., zoning codes, master plans, legal procedures) and informal institutions (e.g., social norms, political influence, customary practices) that shape actual land use outcomes.
- **Exogenous Variables**: These include biophysical conditions (e.g., urban density, infrastructure), socio-economic trends (e.g., population growth, car dependency), and cultural-political settings.

The model aims to generate better-aligned, participatory, and adaptable land use policies that respond to dynamic urban conditions, such as TOD strategies. This framework emphasizes the need to move beyond purely technocratic planning and integrate contextualized governance, cross-sector collaboration, and bottom-up inputs into Iran's land use planning process (Ramezani et al., 2023).

Conceptual model for improving Iran's LUP

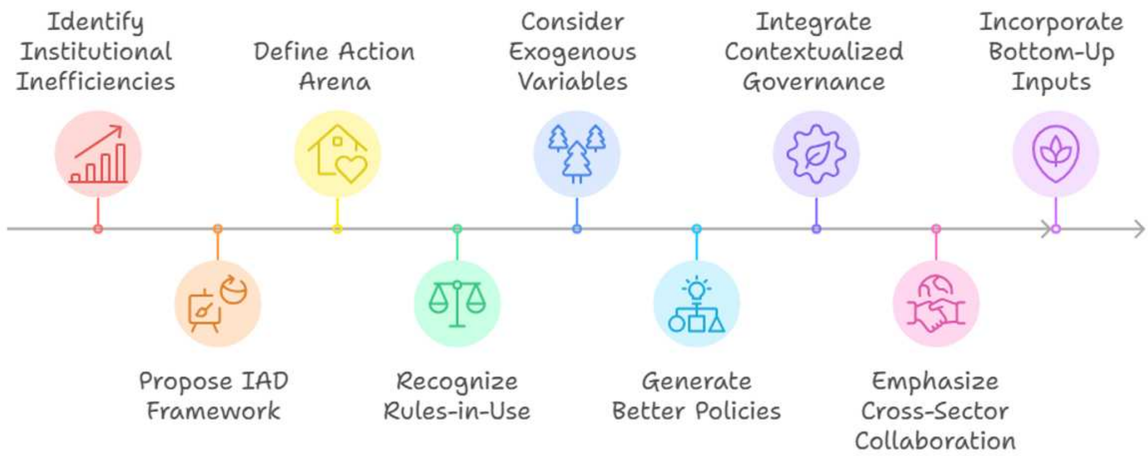


Figure 8 Proposed Conceptual Model for Improving Iran's LUP by author

2.6.1 Urban Transportation Policy and Planning in Iran

Urban transportation planning in Iran has evolved within a context of rapid motorization, institutional centralization, and limited integration with land use policies. Although the country has taken formal steps toward aligning with global sustainable mobility trends, such as the introduction of national TOD guidelines, it continues to face structural and practical challenges that hinder the realization of integrated and transit-supportive urban development.

The growth of private vehicle ownership in Iran has been unprecedented in the past two decades, with annual increases estimated at around 15% (Soltani, 2017; OICA, 2015). This growth has not been matched by a proportional expansion or improvement in public transportation (PT) systems. Despite the development of metro and BRT services in major cities like Tehran, Mashhad, and Shiraz, urban mobility is still predominantly supported by conventional buses, which are often outdated, overcrowded, and poorly maintained. These buses suffer from limited service coverage, especially in newly developed satellite towns such as *Maskan-e-Mehr*, and typically lack dedicated bus lanes or priority infrastructure. As a result, their reliability and efficiency remain low (Mirmoghtadaee, 2016).

Due to these deficiencies, informal and semi-formal transport modes such as shared taxis, motorcycles, and ride-hailing platforms (e.g., SNAP) [4]have filled the gap. In Tehran, for example, taxis account for more than 20% of daily trips, while in smaller cities this share can exceed 80%, reflecting the absence of viable public transport alternatives (Soltani & Falah Manshadi, 2017).

A fundamental shortcoming of Iran's transportation system is the absence of multimodal connectivity and spatial coordination. Transit stations in many cities are disconnected from pedestrian and cycling networks, functioning as isolated infrastructures rather than integrated urban hubs. Walkability is generally poor, and cycling has declined significantly in traditional bicycle-friendly cities such as Isfahan and Yazd. Non-motorized transport (NMT) remains underrepresented in engineering practices and planning documents, despite its potential to support sustainable and inclusive mobility (Mirmoghtadaee, 2016; Abdi & Lamíquiz-Daudén, 2021).

Another structural issue lies in the weak integration between inter-city and intra-city transport systems. Main train stations are often located far from urban centers and lack feeder connections, making regional rail inaccessible to many urban residents. Similarly, urban-suburban connections, particularly in recently developed areas, are fragmented and inefficient, further increasing car dependency (Mirmoghtadaee, 2016; Abdi & Lamíquiz-Daudén, 2021).

Governance and policy fragmentation also pose major barriers. While Iran's Ministry of Roads and Urban Development (MRUD) and the Ministry of Interior (MOI) both play roles in urban transport planning, their mandates often overlap, and coordination is limited. Municipal governments frequently lack the authority, technical capacity, or financial resources to execute comprehensive and coherent transport strategies. Moreover, the existence of separate bodies managing buses, taxis, and rail systems contributes to a siloed approach that undermines integrated mobility solutions (Ramezani et al., 2023). The institutional complexity of urban transport planning in Iran is illustrated by the multitude of national and local bodies with overlapping mandates. Figure 9 below summarizes these relationships and highlights the fragmentation and top-down hierarchy that shape transport policy implementation in Iranian cities.

[4] Snap is Iran's leading ride-hailing platform, launched in 2014, offering on-demand taxi services via a mobile application, similar to Uber.

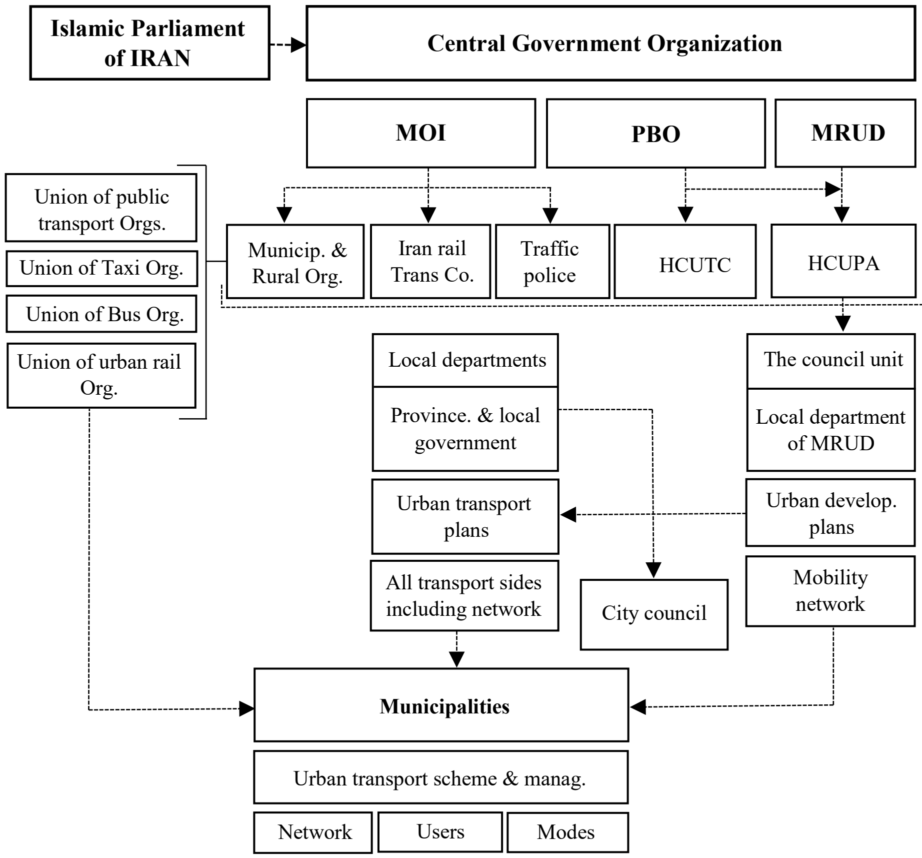


Figure 9 brief structure of the relationship between the organizations engaged in urban planning and transportation planning. Source: https://doi.org/10.1016/j.jtrangeo.2021.103005

Institutions/ Entity	Affiliations	Tier	Key functions/duties
Islamic Parliament of Iran	Legislature	National	Legislation/policymaking, national budget plan
PBO	Central government	National	Preparing technical guidelines including urban and transport plans and making decisions on transport projects and funding
HCUTC And Its Local Departments	MRUD	National / Local	Policymaking, Planning, Coordination, Supervision (of urban plans)
Iranian Rail Transportation Co.	MOI	National	Coordination urban rail organization, accelerating urban metro projects, decreasing costs, localizing equipment production
Traffic Police Department	MOI	National / Local	Road traffic management and enforcement of the regulations
Municipalities and Rural Administrative Organization	MOI	National	All municipality affairs including financial support of municipality plans
Union of National Public Transportation Organization	MOI	National	Coordination and solidarity of public transportation organizations of municipalities (under 100000vinhabitants across Iran)
Union of National Taxi Organization	MOI	National	Coordination, assistance, education of taxi organizations across Iran
Union of National Bus Organization	MOI	National	Coordination, assistance, education of bus organizations across Iran
Union of National Urban Rails	MOI	National	Corporation and assisting urban rail companies across Iran, and interaction with upper entities
Institute of Transportation and Intelligent System	Tehran Polytechnic University	National	Research on the applications of ITSs in urban transportation
City Council	MOI	Local	Budgeting
Traffic and Transportation Organization/Deputy	Municipality (MOI)	Local	Infrastructure constructing, traffic engineering, management, supervision

Table 3 list of national and local entities engaged in urban transportation planning and management
Source: https://oa.upm.es/67356/1/MOHAMMAD_HAMED_ABDI.pdf

Economic policy also interferes with transportation reform. The longstanding policy of fuel subsidies has kept gasoline prices artificially low, reinforcing car dependence and discouraging the use of public transport. According to the National Iranian Oil Products Distribution Company (NIOPDC, 2018), the transport sector accounts for nearly 58% of total oil consumption in the country, highlighting the environmental and fiscal burden of the current mobility model.

Despite these challenges, Iran has made some progress in developing a national TOD framework and updating its urban street design codes. These guidelines reflect an awareness of international best practices and the need for urban environments that support public transport, walkability, and compact development. However, implementation remains limited. Isolated projects - such as pedestrianization initiatives, Park-and-Ride facilities, or bike-sharing trials - have emerged, but they are often disconnected from broader land use strategies and are rarely scaled across cities.

Institutional inertia and cultural resistance also delayed progress. While formal transport plans often mention alignment with comprehensive and detailed urban plans, in practice there is little coordination. Political lobbying and informal influence can override planning logic, further distorting transport policy outcomes. Participatory planning remains weak, and communities have limited input into mobility decisions that affect their daily lives (Ramezani et al., 2023).

Addressing these challenges will require a comprehensive overhaul of both governance structures and planning practices moving toward integrated, multimodal, and participatory approaches capable of supporting transit-oriented and sustainable urban futures.

2.7 TOD design principles

Transit-Oriented Development (TOD) has emerged as a globally recognized planning strategy that addresses the deficiencies of post-war modernist urban models - particularly their reliance on automobile travel, rigid land-use separation, and inefficient spatial patterns (Calthorpe, 1993; Suzuki, Cervero, & Iuchi, 2013). Unlike sprawling, car-dominated urban forms, TOD integrates transit and land-use planning to promote compact, mixed-use, and walkable environments centered around high-capacity public transport nodes.

In the United States, TOD evolved in conjunction with the New Urbanism movement. Peter Calthorpe (1993) was a key proponent, conceptualizing TOD as a neighborhood-based model within a 400–800-meter radius of transit stations, emphasizing pedestrian-scale design, integrated land uses, and public spaces. These principles were later institutionalized through practical guidelines by the Urban Land Institute (ULI) and the Transit Cooperative Research Program

(TCRP). TCRP Report 52 (2002) identified core elements such as density, land-use mix, street connectivity, and vibrant public spaces as essential for TOD. Ewing and Bartholomew (2013) further refined these concepts by focusing on urban design characteristics that enhance pedestrian comfort, human-scale form, and the interface between buildings and transit facilities.

In Japan, TOD implementation has been led by private railway companies that coordinate transit infrastructure with high-density, vertically integrated developments. Cities like Tokyo and Yokohama exemplify TOD models in which residential, commercial, and public services are co-located around transit hubs. These station areas serve as economic and social anchors, supporting high transit ridership while reducing automobile dependency (Suzuki et al., 2013). The Japanese experience demonstrates the effectiveness of long-term coordination between transport and land development, supported by compact urban form and strong private-sector engagement.

European cities have also advanced TOD within broader frameworks of sustainability, climate adaptation, and equitable urban development. In cities such as Freiburg, Copenhagen, and Rotterdam, TOD design principles are embedded in wider policies that prioritize green infrastructure, affordable housing, cycling networks, and inclusive public space. Here, TOD extends beyond transit access to support place-making and urban quality at both neighborhood and metropolitan scales (Suzuki et al., 2013; Ewing & Bartholomew, 2013).

In contrast, TOD practices in Iran - particularly in Tehran - have been largely infrastructure-driven, focusing on metro network expansion with limited integration of land use and design around stations. Although Tehran's metro system is one of the largest in the region, many stations are situated in monofunctional or institutionally restricted zones, including lands owned by military or state bodies. These areas often lack pedestrian accessibility, functional diversity, and integration with the surrounding urban fabric (Abdi & Lamíquiz-Daudén, 2021).

Despite the inclusion of TOD-related principles in strategic plans such as the *Tehran Comprehensive Plan* (2007) and the *National TOD Guideline* (2020), actual implementation has been hindered by rigid zoning regulations, weak inter-agency collaboration, and the absence of design-led planning frameworks. The National TOD Guideline emphasizes mixed land use, pedestrian access, and open space planning but lacks enforceable mechanisms for negotiating institutional barriers - such as dealing with military ownership or integrating different planning authorities (Abdi & Lamíquiz-Daudén, 2021; Mirmoghtadaee, 2016).

Furthermore, public space design around transit nodes in Iranian cities often remains underdeveloped or neglected. Little attention is given to walkability, human-scale design, or civic presence in these areas. In contrast to international cases where TOD is approached as a catalyst for urban vitality, economic productivity, and sustainability, Tehran's station areas frequently lack active frontages, civic amenities, and mixed-use vibrancy (Ewing & Bartholomew, 2013; Suzuki et al., 2013).

To address these deficiencies, TOD planning in Iran must evolve from a narrow focus on transit proximity to a broader engagement with urban form, land-use integration, and institutional reform. Key priorities include strengthening pedestrian and cycling connectivity, enabling diverse land uses, and fostering inter-agency coordination through shared land-use agreements and phased redevelopment. Tactical urbanism and incremental interventions may also serve as practical tools for activating underperforming station areas in the short term (Abdi & Lamíquiz-Daudén, 2021).

This thesis builds on these insights by proposing a design-oriented TOD framework tailored to the Iranian context. It focuses specifically on underutilized and institutionally constrained station areas, integrating international best practices with context-sensitive strategies for improving spatial integration, functional diversity, and public realm quality, key ingredients for transforming transit infrastructure into livable and dynamic urban places.

Urban Design Topic	Dimension	TOD Design Guidelines / Best Practices
Density	Residential & job intensity	• Encourage medium to high-density housing within 400–800m of stations • Increase FAR around major nodes
Land Use Mix	Functional diversity	• Integrate residential, commercial, and civic uses in walkable proximity • Avoid mono-functional zoning
Connectivity	Street network & permeability	• Use grid or semi-grid street layout • Ensure frequent intersections and visual corridors
Walkability	Pedestrian access & comfort	• Provide wide, shaded sidewalks • Prioritize pedestrian crossings, short blocks, and minimal barriers
Public Space	Social use & civic identity	• Design plazas, pocket parks, and transit plazas • Include flexible, multi-use spaces for daily activity
Building Orientation	Relationship to public realm	• Place building entrances toward streets and transit • Avoid blank walls; ensure active ground floors
Public Realm Activation	Street-level uses	• Include small shops, services, cafés, and kiosks at ground floor • Support extended hours of use
Green & Open Space	Environmental integration	• Provide linear parks and bioswales along corridors • Use green buffers between transport and housing
Transit Interface	Station area layout & transitions	• Design forecourts and station plazas as community gateways • Integrate transit stops with civic uses
Parking & Access	Multi-modal balance	• Minimize surface parking• Promote shared and underground parking • Integrate cycling and ride-share options
Legibility & Wayfinding	Orientation & signage	• Use clear signage, tactile paths, and lighting • Enhance visual connections between transit and landmarks
Safety & Inclusivity	Universal design	• Ensure accessibility for elderly and disabled • Provide lighting, ramps, and CPTED principles

Table 4TOD-Oriented Urban Design Topics, Dimensions, and Best Practice Guidelines
Source: Compiled by the author based on (Abdi & Lamíquiz-Daudén, 2021; Mirmoghtadaee, 2016)

2.7.1 Place–Function–Design: A Land Use-Oriented Framework for TOD Implementation

Transit-Oriented Development (TOD) literature has widely employed a set of spatial metrics, commonly referred to as the "3Ds" (Density, Diversity, and Design) or "5Ds" (adding Destination accessibility and Distance to transit) - as tools for evaluating and promoting transit-supportive urban forms (Cervero & Kockelman, 1997; Ewing & Cervero, 2010). These indicators have proven valuable in measuring TOD potential, particularly through GIS-based assessments that quantify urban form characteristics and accessibility. However, scholars have increasingly critiqued these frameworks for focusing heavily on form and proximity, often overlooking the socio-functional and institutional dimensions of space (Vale, 2015; Bertolini et al., 2012).

In contexts such as Tehran, where rigid zoning regulations, fragmented land ownership, and mono-functional urban zones prevail, the limitations of indicator-based TOD models become especially apparent (Abdi & Lamíquiz-Daudén, 2021; Mirmoghtadaee, 2016). Metro stations in Tehran, despite rapid network expansion, are frequently located in areas dominated by single-use government or security facilities, fenced institutional lands, or disconnected public spaces that do not support everyday pedestrian activity or functional diversity.

To address these challenges, this study proposes the **Place–Function–Design (PFD)** framework as a conceptual and operational model for TOD planning in land-constrained, institutionally complex urban environments. The framework builds on several key strands of urban theory. First, it draws on Gehl's (2010) theory of behavior-centered urban design, which emphasizes human-scale environments and the lived experience of public space. Second, it incorporates Mehta's (2014) performance-based planning lens, which focuses on the functional and social productivity of urban spaces. Third, it reflects the insights of Healey's (1997) place-based governance theory, which underscores the importance of institutional negotiation, spatial context, and participatory engagement in planning processes.

Within this integrated approach:

- ✓ **Place** refers to the spatial identity, symbolic value, and continuity of a location within its urban fabric. This dimension accounts for the human perception of place and its embeddedness in everyday urban life (Gehl, 2010; Healey, 1997).
- ✓ **Function** addresses both intended and actual uses of space, including residential, commercial, institutional, and recreational activities, with an emphasis on their contribution to socio-economic inclusivity and urban vitality (Mehta, 2014; Cervero et al., 2002).
- ✓ **Design** considers the built form, spatial legibility, accessibility, and physical comfort that influence usability and mobility, particularly in relation to non-motorized and transit-based travel (Ewing & Bartholomew, 2013; Gehl, 2010).

The National TOD Guideline of Iran (2020) acknowledges the need for integrated, multi-scalar, and flexible land-use planning around transit stations, especially in areas affected by institutional restrictions. However, it lacks clear implementation mechanisms for negotiating with military or government landholders, managing incremental redevelopment, or tailoring TOD strategies to context-specific realities (Abdi & Lamíquiz-Daudén, 2021). The PFD framework responds to this policy gap by offering a flexible structure that combines spatial logic, programmatic performance, and design articulation - making it particularly useful for the Iranian context.

Framing station areas through the PFD lens enables planners to move beyond rigid zoning systems and engage more directly with land governance issues, behavioral dynamics, and spatial opportunities. This approach is consistent with recent calls in the TOD literature to bridge the gap between form-based indicators and functional realities through place-based, context-sensitive design and governance (Bertolini et al., 2012; Vale, 2015).

In this thesis, the PFD model is applied to selected underperforming station areas in Tehran to evaluate their current conditions and propose scalable, phased interventions. The framework offers a grounded methodology for aligning international TOD principles with Iranian urban development constraints, emphasizing land-use restructuring, institutional negotiation, and spatial activation as central mechanisms for implementation.

Figure 10 TOD Lifestyle Scenario: Daily Activities in a Transit-Oriented Neighborhood
Source: Adapted by the author based on an original illustration by ITDP

TOD Designing Theme		Review Theme	Status Quo
PLACE	Urban form & spatial growth	Urbanization	Rapid urban expansion and polycentric sprawl have resulted in car-dependent, low-density developments with limited support for transit or NMT integration.
	Pedestrian connectivity	Walking & biking	Walking and cycling infrastructure is underdeveloped; car-oriented street design undermines non-motorized travel and limits first-last mile access to PT.
	Public realm quality	Urban space design	Public spaces near stations are often fenced, inactive, and lack functional or civic identity, discouraging social use and accessibility.
	Spatial integration of transit	Transport impacts	Transit systems have weak spatial integration with surrounding urban fabric, and are not leveraged to structure compact or mixed-use neighborhoods.
	Land use surrounding transit nodes	Urban structure	Station areas are dominated by mono-functional zones, often controlled by institutional actors, creating disconnected and unresponsive built environments.
FUNCTION	Land use mix & intensity	Public transport / Para-transit	Station areas lack functional diversity; informal transport competes with PT, and station environments fail to support daily needs or sustained activity.
	Housing policies & affordability	Housing policies	Affordable housing policies exist, but lack spatial and functional integration with PT. New housing often neglects proximity to transit access.
	Urban regeneration & programming	Urban regeneration policies	Regeneration efforts favor car accessibility over walkability and transit-supportive densities; TOD principles are rarely translated into practice.
	Land governance & use control	Urban land management	Complex land assembly, state land control, and speculative markets restrict the functional adaptation of land for TOD purposes.
	Institutional function alignment	Urban plans / Private cars	Urban plans remain car-centric despite policy shifts; planning and actual land use decisions remain disconnected from TOD objectives.
DESIGN	Physical form & scale	Physical structure	Urban design still favors vehicular flow; TOD-supportive urban forms - like pedestrian streets, active edges, and transit plazas - are largely absent.
	Human-scale infrastructure	Transport impacts	Station areas lack shading, rest zones, safe pedestrian crossings, and universal accessibility, reducing TOD usability especially for vulnerable groups.
	Built environment-transit linkage	Transport land-use integration	Station design is rarely coordinated with adjacent urban development; urban design strategies at the station scale are often missing or weakly enforced.
	Design governance & implementation	The structure / Municipality	Fragmented institutional roles, weak municipal authority, and sectoral planning result in inconsistent or delayed TOD design implementation.
	Public participation in design	City council	Local councils have limited involvement or influence in shaping station area design; user needs are rarely reflected in final spatial outcomes.

Table 5 TOD Design Themes in the Iranian Context: A Synthesis of Review Themes and Current Status
Source: Compiled by the author based on literature including Cervero & Kockelman (1997), Gehl (2010), Suzuki et al. (2013), Ewing & Cervero (2010), Abdi & Lamíquiz-Daudén (2021)

2.8 Gaps in the Existing Literature

Despite a growing body of literature on Transit-Oriented Development (TOD), particularly in developed countries, there remain significant knowledge gaps concerning its application and effectiveness in cities of the Global South, including Tehran. Most existing research has focused on the successful implementation of TOD in well-established urban planning systems in North America, Europe, and East Asia (Cervero & Sullivan, 2011). While these case studies provide important insights into best practices, they often overlook the unique challenges of rapidly urbanizing cities with complex institutional arrangements, informal development patterns, and fragmented transportation governance - as is the case in Tehran.

One major gap is the lack of empirical, data-driven studies that assess the socio-economic impacts of TOD in Tehran. While several studies explore TOD potential and implementation, few investigate how TOD influences property values, affordability, social equity, and employment opportunities around transit hubs. In contrast, studies in cities like London and New York have demonstrated clear links between TOD and processes such as gentrification, displacement, and rising land values (Zuk et al., 2017). However, similar analyses in Tehran are scarce, leaving a critical gap in understanding whether TOD in the city promotes inclusive development or exacerbates socio-spatial inequalities (Motieyan & Mesgari, 2017).

Another overlooked area is the effectiveness of existing TOD policies in Tehran in addressing environmental concerns, particularly traffic congestion and air pollution. While TOD is globally recognized for its ability to reduce greenhouse gas emissions through increased transit ridership and reduced reliance on private vehicles (Suzuki et al., 2013), few studies have assessed whether these outcomes are being realized in Tehran. Given the city's severe air quality issues and high rates of car ownership, this area of research is particularly urgent.

Moreover, the literature lacks comparative studies between Tehran and other regional cities, such as Istanbul or Dubai, which share similar demographic pressures, urbanization trends, and policy ambitions for TOD. Comparative research could yield valuable insights into how governance models, investment frameworks, and cultural preferences influence TOD outcomes in different Middle Eastern contexts. Such studies would enhance our understanding of how transferable global TOD models are across regional planning environments.

In addition, although various theoretical frameworks have been applied to TOD research globally, their local applicability in Iran remains underexplored. Much of the existing Iranian literature references universal TOD principles but does not adequately assess how these align - or conflict -

with Tehran's centralized governance structures, outdated planning instruments, and market-driven development practices. There is a need for a more nuanced exploration of how global TOD frameworks (such as ITDP and 3D/5D) can be adapted to Iran's institutional, cultural, and economic realities (Mirmoghtadaee & Abdi, 2021).

This study aims to bridge these gaps by conducting a comprehensive, spatially-informed evaluation of TOD performance across Tehran's metro stations, focusing particularly on land use integration, socio-economic inclusivity, and pedestrian accessibility. It incorporates localized indicators and comparative scoring methods, as well as spatial analysis techniques to classify TOD potential. By aligning international best practices with Tehran's specific context, this research seeks to develop actionable, evidence-based recommendations that contribute to more sustainable and equitable TOD outcomes.

Chapter 3

Research Methodology and Study Area Definition

3.1 Study Area Definition: TOD Challenges in Tehran's Metro System

Tehran, the capital and largest metropolis of Iran, stands as a complex urban ecosystem facing profound challenges related to mobility, land use, and environmental sustainability. With a population of over 9 million in the urban core and nearly 15 million in the wider metropolitan area, Tehran represents approximately one-sixth of Iran's entire population. As a major political, economic, and cultural hub, the city is emblematic of the urbanization pressures seen across the Global South - characterized by rapid growth, spatial inequality, infrastructure strain, and rising automobile dependency. These dynamics make Tehran a particularly important and instructive case for investigating the application of Transit-Oriented Development (TOD).

Tehran's extensive public transportation network, particularly its metro system, offers a strong foundation for TOD initiatives. With over 250 kilometers of track and more than 150 stations in operation across seven lines, the Tehran Metro is one of the largest in the Middle East. It serves over 2 million passengers daily, providing critical mobility for urban residents. However, despite this capacity, the metro remains underutilized relative to its potential due to structural inefficiencies in land use, station area design, and institutional coordination. These factors limit the metro's effectiveness in shifting travel behaviors away from private vehicles (Arjomand Kermani, M., & Gholamrezai, S. 2024).

Urban travel behavior in Tehran underscores this issue. Studies indicate that over 55% of trips in the city are made by private car, with the shares of metro and bus travel significantly lower than in comparable global cities (Alizadeh & Sharifi, 2023). This car dependency has contributed to severe traffic congestion, air pollution, and energy consumption, making sustainable mobility solutions increasingly urgent. Meanwhile, the city's form reflects a mismatch between infrastructure investments and urban development: the core urban areas are dense and relatively transit-supportive, while suburban and peri-urban districts have developed in sprawling, low-density, and mono-functional patterns - further entrenching car reliance.

From a planning and policy standpoint, Tehran presents both challenges and opportunities. The adoption of Iran's National TOD Guideline in 2020 signals a commitment to aligning urban growth with sustainable transit policies. Nevertheless, implementation has been hindered by fragmented governance, outdated zoning laws, and limited integration between planning institutions and transit authorities (Mirmoghtadaee & Abdi, 2021). At the same time, urban inequality in Tehran - particularly in its southern and eastern districts - exacerbates disparities in access to jobs, services, and public infrastructure. TOD offers a framework to address these issues holistically by promoting compact, mixed-use, and equitable development around transit corridors.

The research value of Tehran lies not only in its scale and complexity but also in its relevance to other cities in the Global South facing similar urbanization pressures. Few cities in the MENA region combine such an extensive metro infrastructure with such acute land use and governance challenges. Moreover, there is a lack of empirical, localized studies assessing TOD performance in Tehran through spatial analysis and policy evaluation. This gap in academic literature presents an opportunity for this research to contribute original insights and practical recommendations for improving TOD planning and implementation.

In summary, Tehran is selected as the case study for this research due to:

- Its extensive but underutilized metro system;
- Its rapidly expanding urban footprint and high automobile dependency;
- The presence of deep-rooted governance, land use, and policy integration challenges;
- Its role as a national and regional model for TOD transformation;
- The critical need for localized TOD frameworks tailored to the realities of Iranian cities.

TOD Challenges in Tehran's Metro System

Despite Tehran's potential as a TOD leader in the region, multiple challenges hinder the realization of its benefits. First and foremost is the limited first- and last-mile connectivity around many metro stations. A lack of seamless integration with pedestrian networks, bicycle infrastructure, and feeder buses reduces accessibility, particularly in peripheral neighborhoods. Narrow sidewalks, missing crosswalks, and poorly maintained public realms further discourage walking and active transport. Another major issue is the incompatibility of existing land uses with TOD principles. Many station areas are surrounded by industrial land, storage facilities, or mono-functional developments that fail to create vibrant, mixed-use urban environments. In several cases, density patterns are either too low to generate meaningful transit ridership or excessively high without supporting infrastructure, resulting in congestion and poor quality of life.

Station areas also suffer from a lack of functional diversity - with limited access to essential services such as retail, healthcare, education, and public spaces within walking distance. This inhibits the creation of complete neighborhoods where people can live, work, shop, and socialize without relying on private vehicles. The segregation of land uses, enforced by outdated zoning codes, undermines TOD's core objective of creating walkable, compact communities.

Land ownership patterns present another obstacle. Many metro station catchments are fragmented among multiple private owners, making it difficult to coordinate redevelopment or pursue integrated planning. The absence of land management tools - such as land readjustment, value capture, or public-private partnerships - hampers the municipality's ability to incentivize TOD-aligned growth.

Lastly, Tehran lacks a dedicated institutional body to oversee TOD coordination. The multiplicity of actors - including Tehran Municipality, the metro authority, district councils, and developers - operates without unified governance or shared performance indicators. This institutional fragmentation results in missed opportunities for synergy and delays in project implementation.

Addressing these challenges requires a comprehensive, multi-scalar strategy that integrates spatial planning, policy reform, and community engagement. The remainder of this thesis aims to assess these dimensions using spatial indicators, field analysis, and policy review - proposing a localized framework for advancing TOD in Tehran.

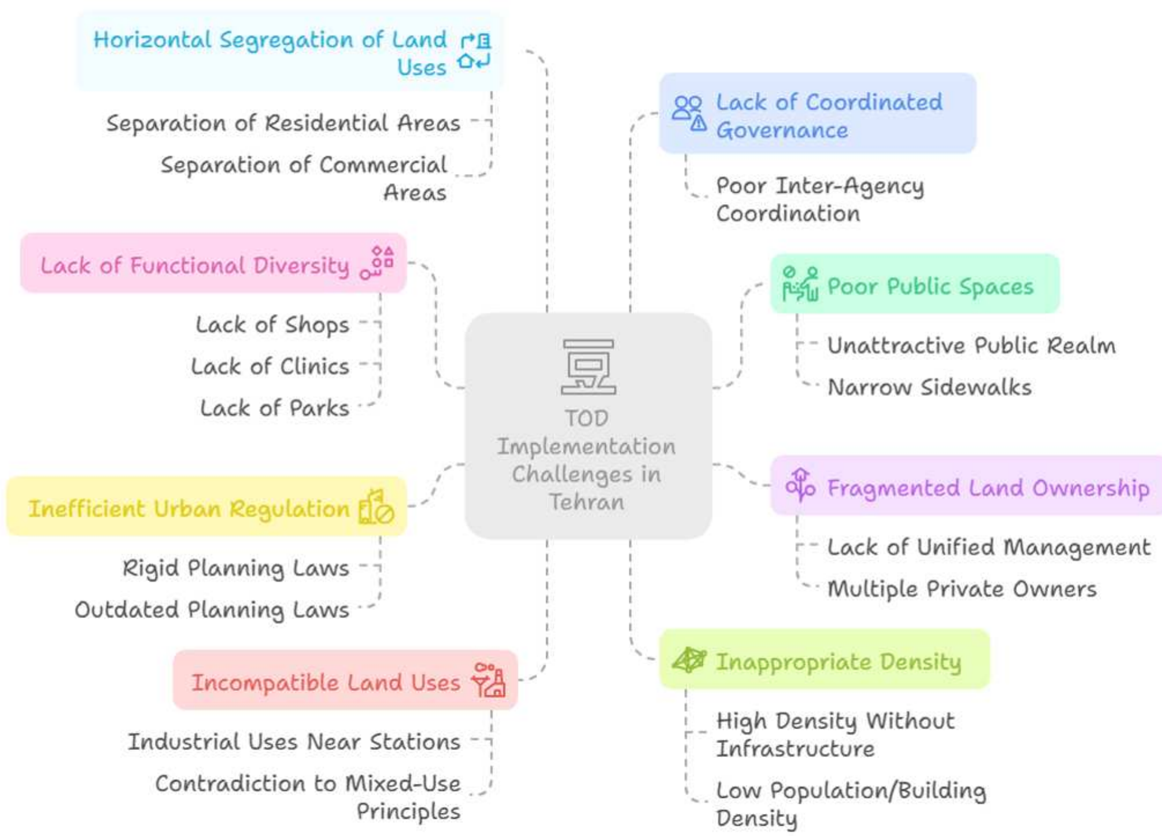


Figure 11 TOD implementation challenges in Tehran, Iran by author

To address these multifaceted challenges, this study aims to systematically evaluate the Transit-Oriented Development (TOD) potential of selected metro stations in Tehran by employing a comprehensive Geographic Information System (GIS)-based spatial analysis framework. Given the increasing importance of TOD in fostering sustainable urban development, this research integrates multiple spatial and statistical techniques to assess the degree to which metro stations align with TOD principles. Specifically, the methodology incorporates Multi-Criteria Evaluation (MCE), clustering techniques such as K-Means, and network analysis to provide a holistic assessment of urban mobility, land use patterns, and accessibility around metro stations.

The selection of these methodological approaches is rooted in their respective analytical strengths and their ability to capture the multidimensional nature of TOD assessment. MCE is employed to systematically evaluate and integrate various spatial indicators, such as land use diversity, population density, pedestrian connectivity, and access to public transport. This approach enables the weighting and ranking of metro stations based on a set of TOD-related criteria, ensuring a structured and objective evaluation process. Clustering techniques, particularly K-Means, are applied to classify metro stations into distinct groups based on their spatial and functional characteristics. By identifying clusters with similar urban and transport attributes, this method facilitates the recognition of metro stations that exhibit higher TOD potential while also distinguishing those requiring targeted interventions. Additionally, network analysis is utilized to examine the connectivity and accessibility of metro stations within the broader urban transportation system. This technique allows for the assessment of pedestrian and multimodal access, highlighting gaps in last-mile connectivity and potential areas for infrastructural improvements.

The integration of these methodologies enables a nuanced understanding of TOD opportunities and challenges at the station level. The primary objective of this study is to identify metro stations that demonstrate the highest potential for TOD interventions, thereby informing strategic planning and policy recommendations. The findings of this research aim to support urban planners and policymakers in optimizing land use and transportation integration, enhancing urban sustainability, and fostering more walkable and transit-friendly neighborhoods in Tehran. Ultimately, this study contributes to the broader discourse on sustainable urban development by providing data-driven insights into the spatial dynamics of TOD implementation in rapidly growing metropolitan contexts.

3.2 Spatial and Functional Context of Tehran Metro Stations

A comprehensive understanding of the spatial and functional context of Tehran's metro stations is fundamental to achieving the objectives of this research, which focuses on evaluating TOD challenges and opportunities with a special emphasis on land use. The spatial positioning of metro stations, the quality of their surrounding land use patterns, and their functional integration with urban infrastructure play a critical role in determining the success or failure of TOD policies.

Urban Growth and Metro Network Expansion in Tehran

Tehran has undergone rapid urban expansion over the past five decades, driven by population growth, administrative centralization, and uncontrolled suburbanization. This expansion has resulted in a fragmented urban fabric characterized by low-density sprawl, single-use zoning, and a strong reliance on private vehicle use (Mirmoghtadaee, 2009; Khosravi et al., 2024). In response to severe congestion, air pollution, and public transport inefficiencies, the Tehran Metro has been developed as a core public transportation network.

As of 2024, Tehran's metro system comprises 7 operational lines and more than 150 stations, extending over approximately 250 kilometers. While the network has significantly improved macro-level accessibility, the effectiveness of each metro station as a TOD node varies widely depending on its spatial location and surrounding land use characteristics.

Classification of Metro Station Contexts

From a spatial perspective, Tehran's metro stations can be broadly classified into three typologies:

- Central Urban Stations (e.g., Imam Khomeini, Haft-e-Tir): Located in high-density, mixed-use zones with historic urban form, higher pedestrian volumes, and greater land value. These stations tend to align more closely with TOD principles, though often suffer from traffic saturation and infrastructure aging (Mirmoghtadaee & Abdi, 2021).
- Intermediate Stations (e.g., Sadeghieh, Shahr-e-Rey): Located in areas with fragmented land use, uneven density distribution, and partial transit integration. These stations represent transition zones where TOD potential exists but remains underdeveloped due to inconsistent zoning policies and lack of pedestrian connectivity (Motieyan & Mesgari, 2017).
- Peripheral Stations (e.g., Ghaem, Azadegan): Situated in newly urbanized or suburban zones, often adjacent to informal settlements, vacant lands, or mono-functional residential

areas. These locations typically demonstrate low TOD compatibility and require targeted land use reforms and densification strategies (Gharakhlou & Behbahani, 2020).

Functional Gaps in Station-Area Development

Despite their role as mobility hubs, many Tehran metro stations lack the necessary functional qualities to serve as genuine TOD catalysts. Key issues include:

- **Single-use zoning and low land use mix**, especially in peripheral areas, which reduces vibrancy and limits station-area activities beyond peak hours.
- **Poor pedestrian infrastructure**, including limited sidewalks, lack of crossings, and wide arterials that inhibit walkability.
- **Weak multimodal integration**, particularly inadequate access to buses, taxis, and non-motorized modes for first/last-mile connectivity.
- **Undervalued or underutilized parcels** near stations that are either vacant or occupied by low-density uses, reflecting inefficient urban land use.

These patterns reflect a disconnect between land use planning and transit investments, a condition consistently observed in Tehran's urban development literature (Khosravi et al., 2024; Forouhar & Imani, 2019).

Land Use as the Core of TOD in Tehran

Given the thesis focus on land use strategies for TOD optimization, the evaluation of land use patterns around metro stations takes precedence. High-performing TOD zones are typically characterized by:

- A diverse and balanced land use mix (residential, commercial, institutional, recreational),
- Vertical and horizontal compactness, measured by Floor Area Ratio (FAR) and population density,
- Functional integration with urban services and amenities within a walkable 500-meter radius (Arjomand Kermani, M., & Gholamrezai, S. 2024; Shen, Q., et al., 2023).

The selected indicators for this research - such as the Shannon and Entropy Index (for land use mix), FAR, access to services, and walkability index - capture these spatial-functional dynamics and provide a basis for evaluating TOD performance across Tehran’s metro network.

The spatial and functional context of metro stations is critical to realizing the goals of Transit-Oriented Development. As this section demonstrates, while some stations in Tehran exhibit promising TOD characteristics, many suffer from fragmented land use, poor pedestrian environments, and limited multimodal access. These findings support the central argument of this thesis: that land use reform and strategic urban design are essential to unlocking TOD potential in Tehran.

By linking quantitative GIS analysis with qualitative spatial interpretation, this study provides a robust foundation for developing location-specific design proposals and policy recommendations in later chapters.

شرکت راه‌آهن شهری تهران و حومه (مترو)

Tehran Urban & Suburban Railway Company (METRO)

Geospatial Representation of Tehran Metro Lines and Stations

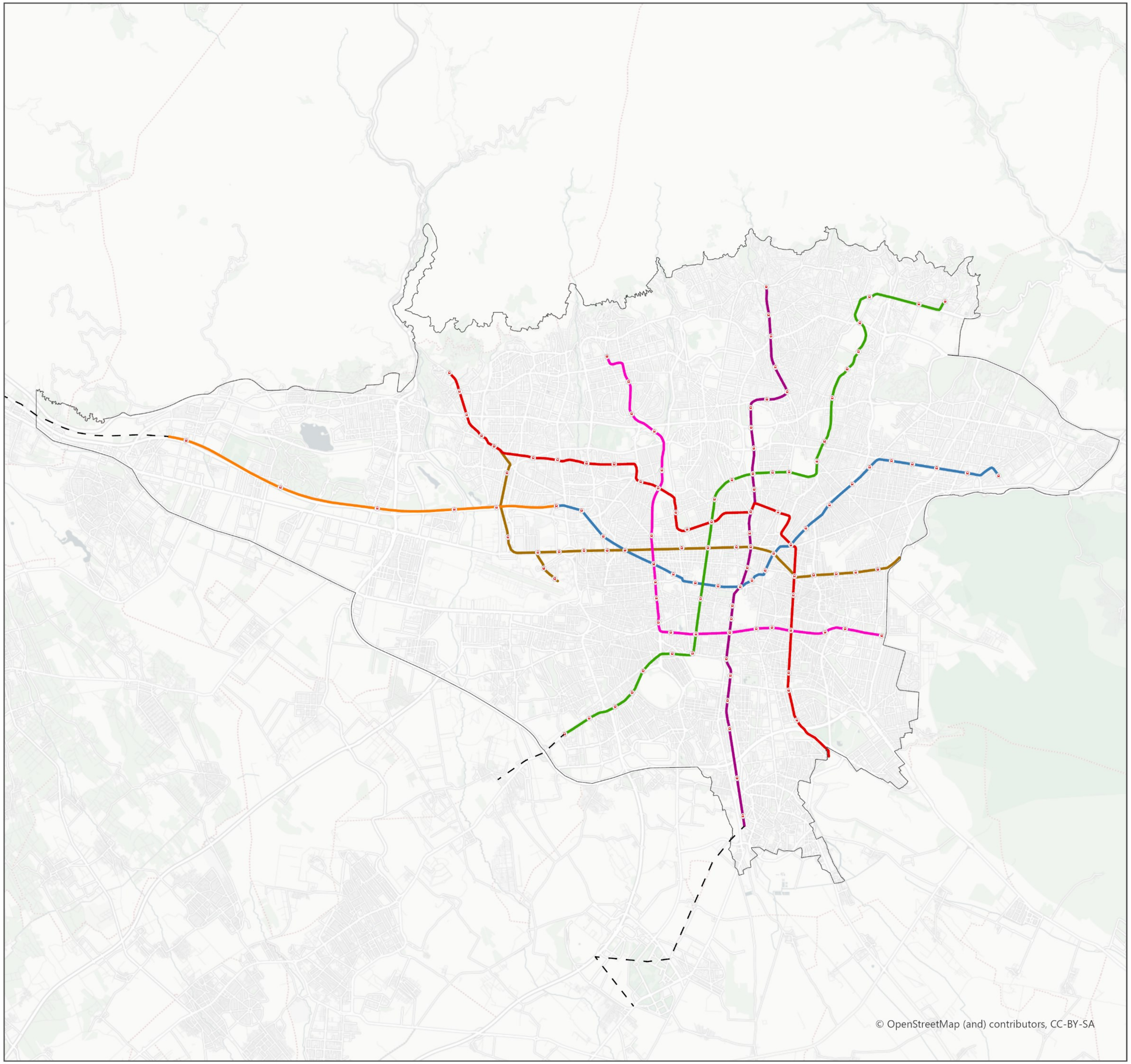
METRO LINE

- Metro Station
- Line 1
- Line 2
- Line 3
- Line 4
- Line 5
- Line 6
- Line 7
- Lines (beyond city limits)
- Tehran Boundary

BaseMap: OpenStreetMap

N

0 3.5 7 14 Kilometers



Map 1

This map created by the author

شرکت راه آهن شهری تهران و حومه (مترو)

Tehran Urban & Suburban Railway Company (METRO)

Geospatial Representation of Tehran Metro Stations Catchment Area

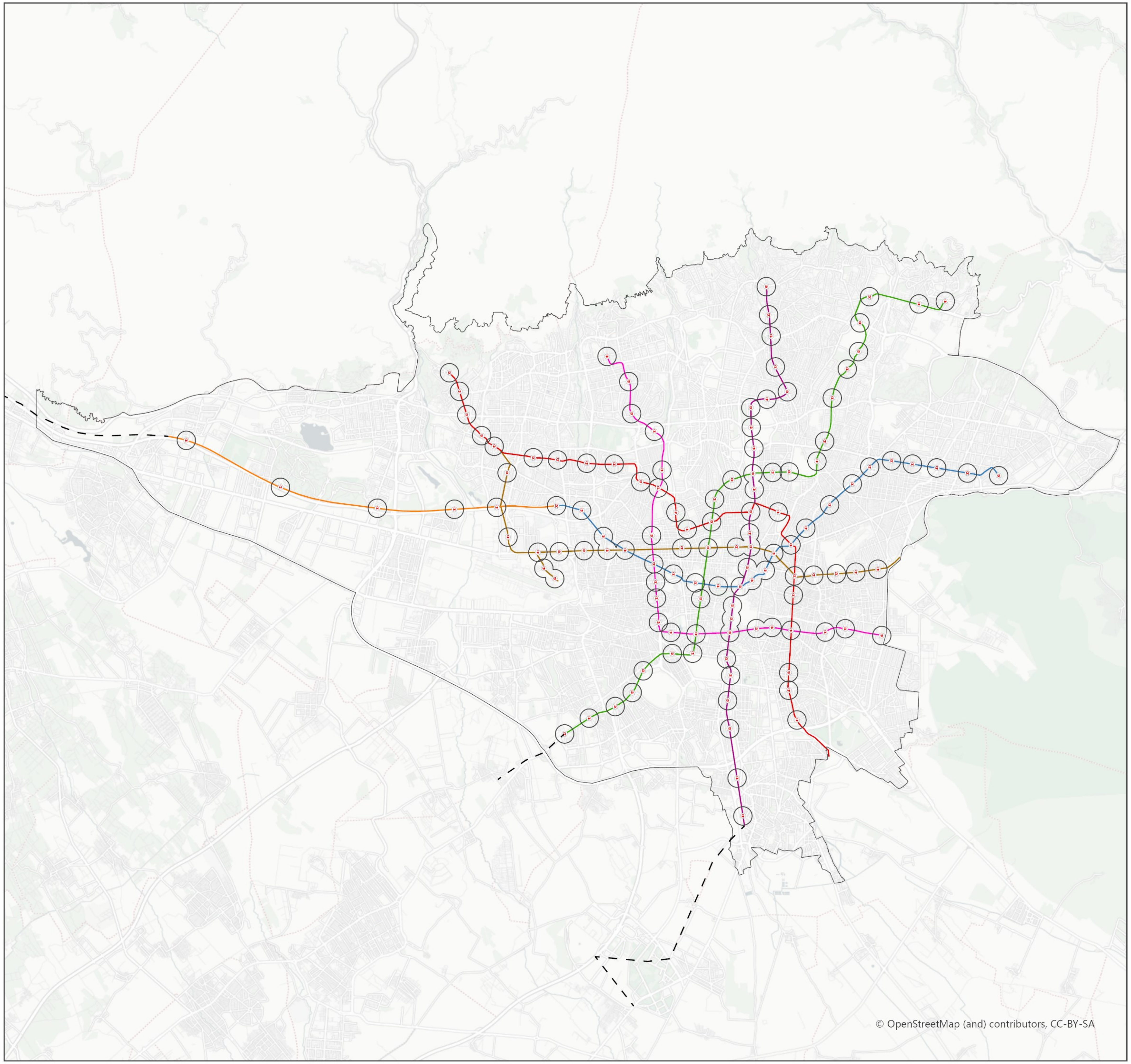
METRO STATION BUFFER ZONE (500M)

- Metro Station
- Line 1
- Line 2
- Line 3
- Line 4
- Line 5
- Line 6
- Line 7
- Lines (beyond city limits)
- Buffer Zone
- Tehran Boundary

BaseMap: OpenStreetMap

N

0 3.5 7 14 Kilometers



Map 2

This map created by the author

شرکت راه‌آهن شهری تهران و حومه (مترو)

Tehran Urban & Suburban Railway Company (METRO)

Geospatial Representation of Tehran Regions Population Density

POPULATION DENSITY
(people / ha)

- 3675.72 - 3886.68
- 3886.68 - 11985.85
- 11985.85- 13365.87
- 13365.87 - 15710.09
- 15710.09 - 20374.16
- 20374.16 - 233750.75
- 233750.75 - 41921.04

- Metro Station
- Line 1
- Line 2
- Line 3
- Line 4
- Line 5
- Line 6
- Line 7
- Lines (beyond city limits)
- Tehran Boundary

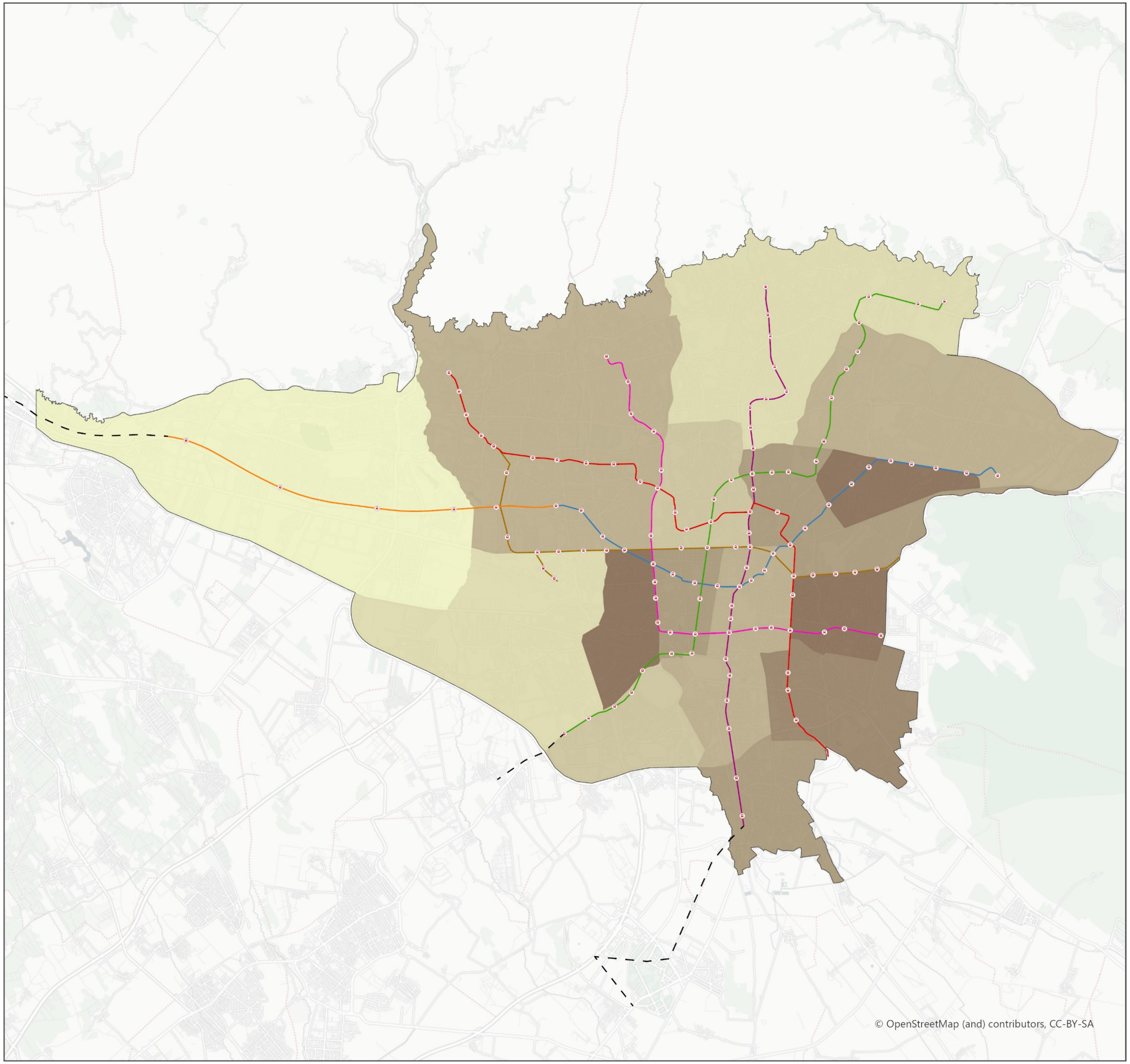
BaseMap: OpenStreetMap

N

0 3.5 7 14 Kilometers

Map 3

This map created by the author



شرکت راه‌آهن شهری تهران و حومه (مترو)
Tehran Urban & Suburban Railway Company (METRO)

Geospatial Representation of Tehran Population Density in Buffer Zone

KERNEL_POPULATION
(people / ha)

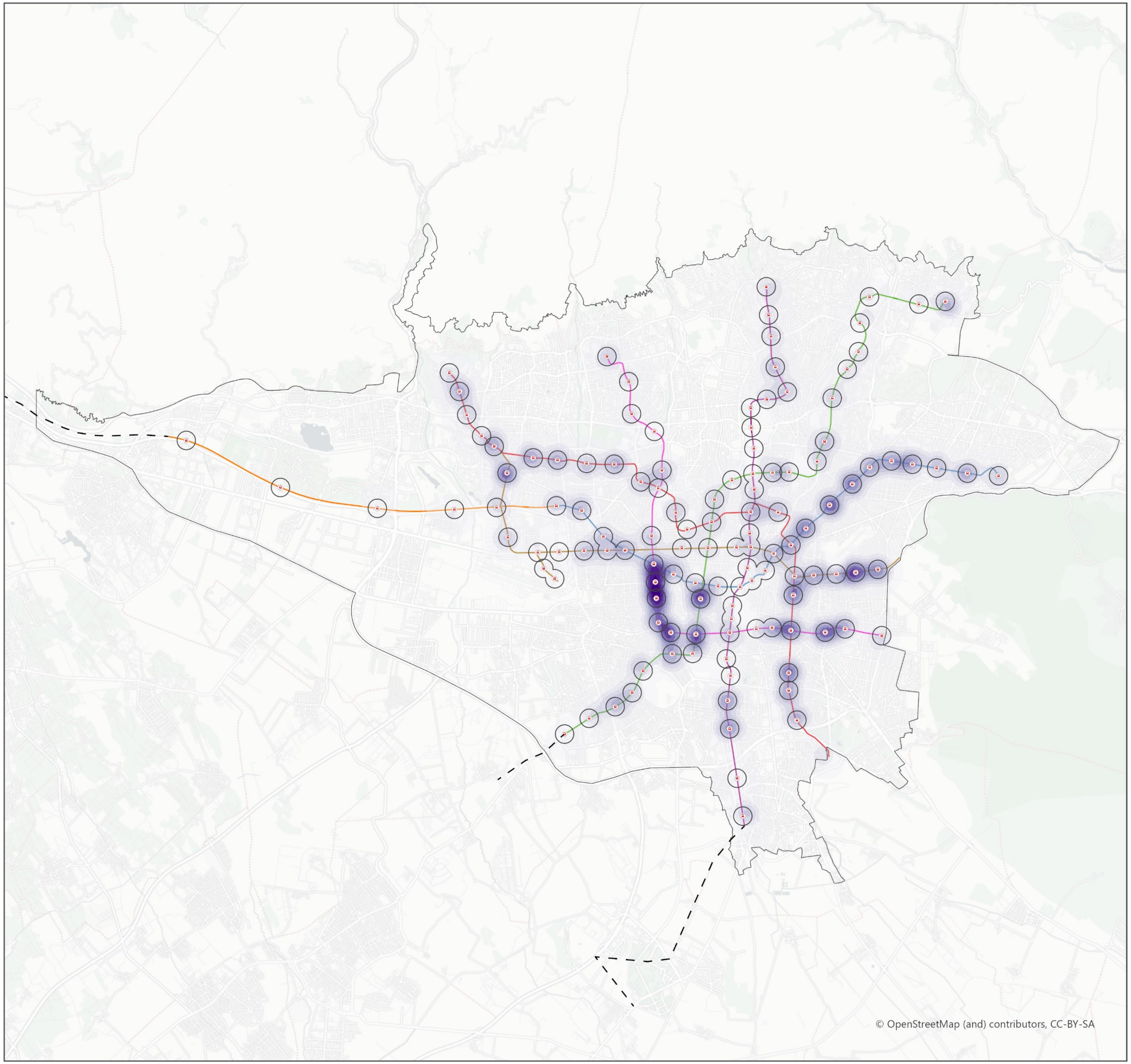
- 0.001 - 0.002
- 0.003 - 0.004
- 0005 - 0.006
- 0.007 - 0.008
- 0.09 - 0.01
- 0.011 - 0.012
- 0.013 - 0.014
- 0.014 - 0.015
- 0.016 - 0.017
- 0.018 - 0.019

- Metro Station
- Line 1
- Line 2
- Line 3
- Line 4
- Line 5
- Line 6
- Line 7
- Lines (beyond city limits)
- Buffer Zone
- Tehran Boundary

BaseMap: OpenStreetMap

N

0 3.5 7 14 Kilometers



Map 4
This map created by the author

شرکت راه‌آهن شهری تهران و حومه (مترو)

Tehran Urban & Suburban Railway Company (METRO)

Geospatial Representation of Tehran Road Network Hierarchy

NETWORK HIERARCHY

- Freeway
- Highway (ramps included)
- Boulevard
- Main Street
- Secondary Street
- Tunel / Bridge
- Metro Station
- Buffer Zone
- Tehran Boundary

BaseMap: OpenStreetMap

N

0 3.5 7 14 Kilometers

Map 5

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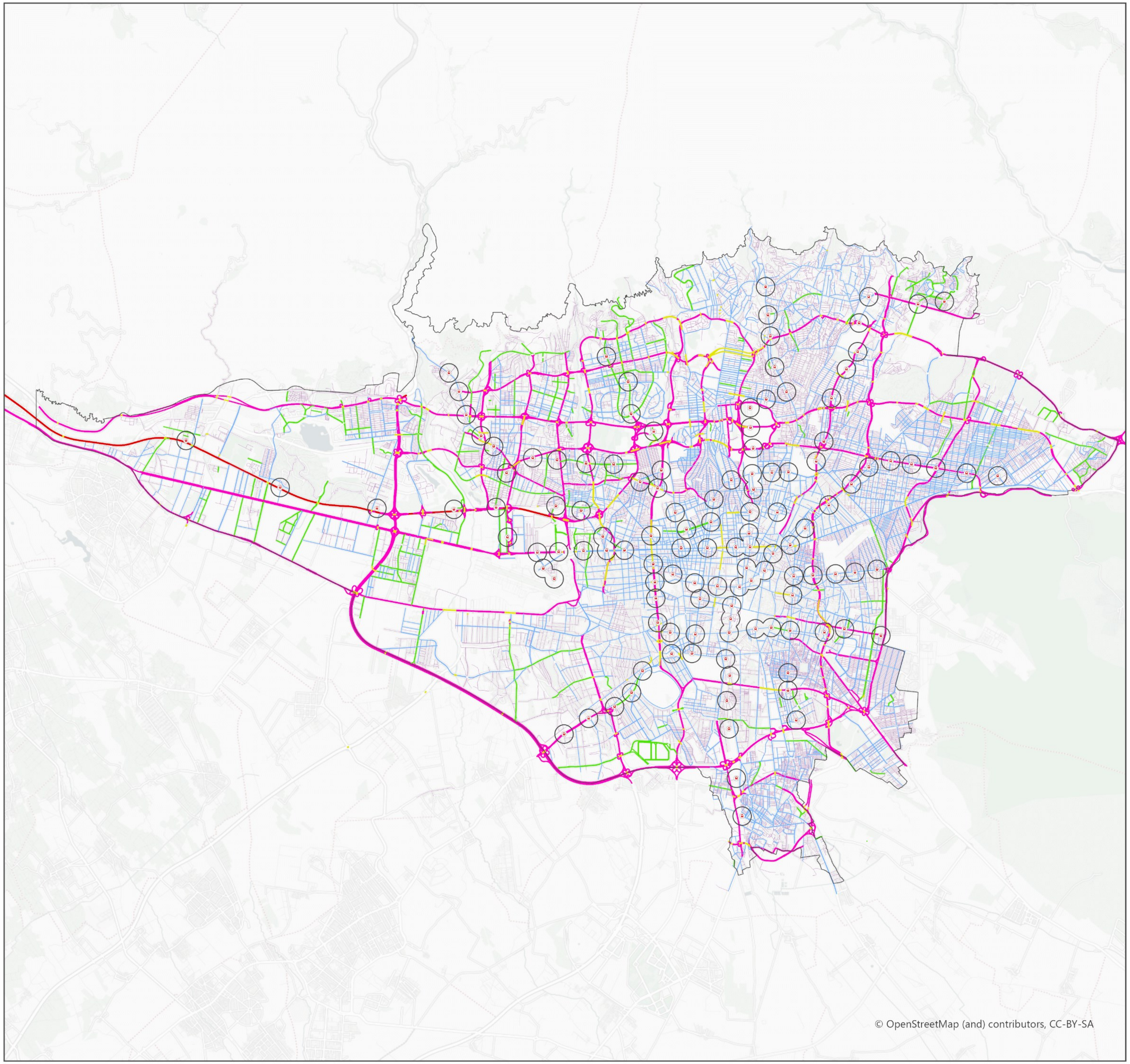


شرکت راه‌آهن شهری تهران و حومه (مترو)

Tehran Urban & Suburban Railway Company (METRO)

Geospatial Representation of Tehran LandUses Zoning

ZONING

- Residential Zone
- Public/Institutional Zone
- Commercial/Mixed-use Zone
- Industrial/Logistics Zone
- Green/Recreational Zone
- Infrastructure Zone
- Metro Lines
- Metro Stations
- Lines (beyond city limits)
- Buffer Zone
- Tehran Boundary

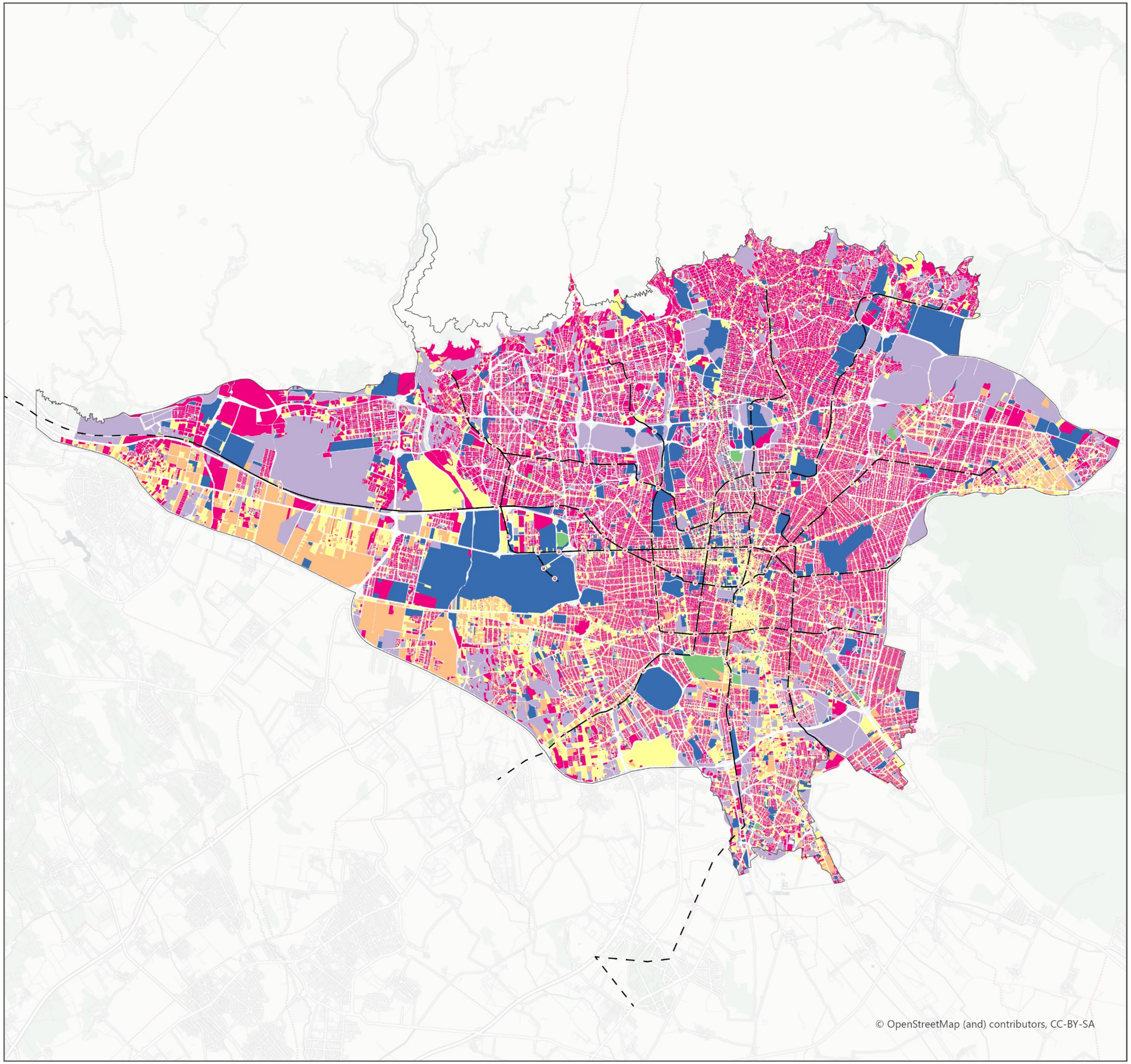
BaseMap: OpenStreetMap

N

0 3.5 7 14 Kilometers

Map 6

This map created by the author



شرکت راه‌آهن شهری تهران و حومه (مترو)

Tehran Urban & Suburban Railway Company (METRO)

Geospatial Representation of Tehran Metro Stations Land Uses

LAND USES

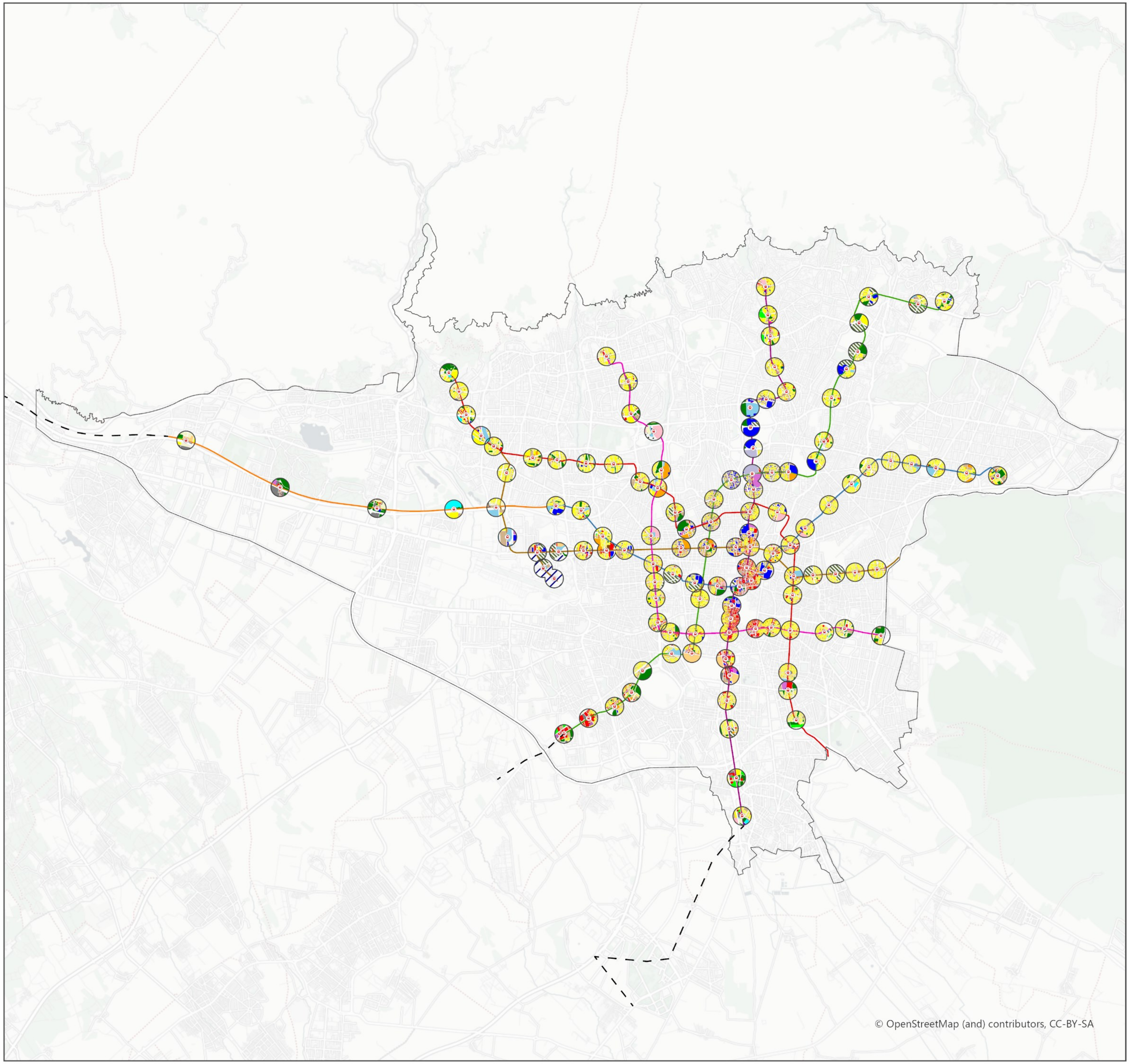
- Residential
- Sport
- Forest-park
- Park/Green spaces
- Parking
- Educational
- Administrative/Police
- Warehouse
- Agriculture/Garden
- Vacant
- Urban Infrastruucture
- Commercial
- Commercial/Administrative/Service
- Commercial/Industrial
- Commercial/Residential
- Urban Equipment
- Recreational/Tourist
- Transportation
- Medical
- Military
- Mixed-use
- Industrial
- Cultural
- Airport
- Religious

- Metro Station
- Line 1
- Line 2
- Line 3
- Line 4
- Line 5
- Line 6
- Line 7
- Lines (beyond city limits)
- Buffer Zone
- Tehran Boundary

BaseMap: OpenStreetMap

N

0 3.5 7 14 Kilometers



Map 7

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3.3 Research Method and Data Sources

This research adopts a two-phase GIS-based methodology to systematically evaluate the Transit-Oriented Development (TOD) potential of metro stations in Tehran. The methodological foundation is built upon the 5D framework, which is widely used in TOD literature and urban transportation planning. This framework evaluates station areas through five key dimensions:

- ✓ **Density**
  High population and building density are essential for generating sufficient demand for public transportation. Dense urban environments support frequent and financially viable transit services while reducing the need for car ownership. Density also enables more people to live, work, and access services within walking distance of transit hubs, thus enhancing ridership and reducing sprawl.
- ✓ **Diversity**
  A diverse mix of land uses (residential, commercial, educational, recreational) within walking distance of transit encourages short, non-motorized trips and reduces the need for long commutes. Land use diversity enhances the vibrancy and activity levels around stations, making them safer and more attractive throughout the day and night.
- ✓ **Design**
  Urban design shapes the pedestrian experience. Well-designed public spaces, connected street networks, adequate sidewalks, and high intersection density promote walkability and bicycle use. These features are critical for supporting “first and last-mile” connectivity and ensuring that transit is accessible and inviting for users of all ages and abilities.
- ✓ **Destination Accessibility**
  TOD should provide access not only to transit but also to essential daily needs - such as schools, healthcare, jobs, and shopping - within a short walk. Good destination accessibility reduces the need for private vehicle use and enables equitable, compact urban living.
- ✓ **Distance to Transit**
  Ease of access to other transit modes - such as buses, taxis, and feeder systems - is crucial to ensuring seamless multimodal connectivity. TOD is not just about the metro

- it's about building an integrated mobility system. Stations that are well-connected to other modes are more likely to be used and to support low-carbon transport behaviors.

By organizing spatial indicators within these five dimensions, the methodology ensures a multidimensional and integrated evaluation of how well each metro station area aligns with TOD principles in two phases:

- Phase 1 involves the weighting and scoring of TOD indicators under the 5D framework using the Entropy Method, resulting in a composite TOD score for each station.
- Phase 2 applies K-Means Clustering to categorize all metro stations into performance-based groups based on their weighted scores, supporting typological analysis and case study selection using the stratified sampling method.

Phase 1: Indicator Weighting and Composite TOD Scoring

In the first phase, a set of spatial indicators - each corresponding to one of the five TOD dimensions - is calculated using GIS tools for each metro station's 500-meter pedestrian catchment. Examples of indicators include:

- Floor Area Ratio and population density (Density)
- Shannon or Entropy Index for land use mix (Diversity)
- Walkability Index, Road Network Connectivity, Sidewalk Coverage (Design)
- Number of public services within walking range (Destination Accessibility)
- Distance to nearest bus stops or taxi routes and first/last mile connectivity (Distance to Transit)

Once the raw values for these indicators are extracted, they are normalized using min-max normalization, which rescales the data to a 0–1 range. This is necessary because the indicators are measured in different units (e.g., square meters, population counts, distances), and normalization ensures fair comparison and aggregation.
using the following formula:

$$X' = X - X_{min} / X_{max} - X_{min}$$

Where:

- X is the original value of the indicator for a given station
- X_{min} and X_{max} are the minimum and maximum values of that indicator across all stations
- X′ is the normalized value

This process is repeated for all indicators, resulting in a uniform, dimensionless dataset where all indicators have equal numerical influence regardless of their original unit.
Next, Entropy Weighting is applied to these normalized indicators. The Entropy Method is a data-driven technique that calculates the relative importance (weight) of each indicator based on its level of variability across all stations. Indicators that show more variation across the network are considered more influential in differentiating TOD performance and are assigned higher weights. This step removes subjective judgment (such as expert opinion) from the weighting process and enhances the objectivity of the evaluation.

Steps in Entropy Weighting:

1. Calculate the proportion P_{ij} of each station's normalized value for indicator j, relative to the total across all n stations:

$$p_{ij} = \frac{X'_{ij}}{\sum_{i=1}^{n} X'_{ij}}$$

2. Calculate the entropy e_j for each indicator j:

$$e_j = -k \sum_{i=1}^{n} p_{ij} \cdot \ln(p_{ij})$$

where k = 1/ ln(n) is a constant to ensure that entropy values fall between 0 and 1.

3. Calculate the degree of divergence d_j :

$$\mathbf{d_j = 1 - e_j}$$

This measures how much useful information an indicator provides - the greater the divergence, the more important the indicator.

4. Determine the final weight wj of each indicator:

$$w_j = \frac{d_j}{\sum_{j=1}^{m} d_j}$$

Where m is the total number of indicators.

The result is a set of weights (wj) for each TOD indicator that reflects their true discriminating power, based entirely on the structure of the dataset - not expert opinion.

Finally, a composite TOD score is is calculated for each metro station. This is done using a weighted summation model, where each normalized indicator value is multiplied by its corresponding weight, and all are summed:

$$\text{TOD Score}_i = \sum_{j=1}^{m} (w_j \cdot X'_{ij})$$

Where:

- TOD Score $_i$ is the final TOD score for station i
- X_{ij}' is the normalized value of indicator j for station i
- w_j is the entropy-derived weight for indicator j

The resulting score reflects how well each station aligns with TOD principles across the five dimensions (5D). These scores are then used as input for the second phase of the analysis - K-Means Clustering - which classifies stations based on their TOD performance.

Phase 2: K-Means Clustering for Typological Classification

In the second phase of the methodology, the results from the first phase - specifically the composite TOD scores calculated for each metro station - are used to group the stations into categories based on their performance. To do this, the study uses a statistical method called K-Means Clustering.

K-Means is a type of unsupervised machine learning algorithm, meaning it can find patterns in the data without needing pre-labeled groups. In simple terms, the algorithm looks at the TOD score and other key characteristics of each station and identifies groups of stations that are similar to each other. These groups are called clusters. The idea is that stations within the same cluster have comparable spatial qualities and TOD potential, while those in different clusters are more distinct.

In this study, the clustering process was carried out by:

- Feeding the weighted TOD scores - and, in some cases, selected underlying indicators - into the K-Means algorithm.
- Instructing the algorithm to divide the 124 metro stations into four distinct clusters, each representing a different level of TOD performance

- Reviewing the results to ensure that the clusters make sense both statistically and spatially, meaning that the stations in each group are not only similar in numbers but also share real-world characteristics in terms of land use, density, accessibility, and design.

The purpose of clustering in this phase is to move beyond individual station-level evaluation and to uncover patterns across the metro network. Instead of viewing each station in isolation, the clusters provide a typology - or classification system - that helps urban planners, researchers, and decision-makers understand what types of TOD challenges and opportunities exist in different parts of the city.

This classification system has three important practical benefits. First, it enables strategic urban planning by identifying what types of interventions are needed for each group of stations (e.g., infrastructure upgrades, zoning changes, or design improvements). Second, it helps pinpoint priority stations that require urgent attention or offer the greatest potential for successful TOD implementation. Third, it serves as the foundation for selecting eight case study stations - two from each cluster - for more detailed analysis, design proposals, and policy recommendations in later stages of the research.

In summary, this clustering phase transforms raw data and scores into meaningful station categories, helping to guide smarter planning decisions that are tailored to the real spatial and functional differences across Tehran’s metro system.

The integration of the two analytical phases - entropy-based scoring and clustering - forms a data-driven and context-sensitive evaluation model for assessing Transit-Oriented Development (TOD) potential across Tehran’s metro network. This methodological framework allows for the quantification of TOD performance at the station level using objective and measurable spatial indicators, ensuring a structured and transparent assessment process.

By employing the Entropy Method for indicator weighting, the model eliminates the need for subjective expert input, thereby reducing bias and enhancing the statistical reliability of the evaluation. The use of K-Means clustering further strengthens the approach by revealing underlying spatial patterns in TOD performance and grouping stations with similar characteristics into distinct typologies. This enables planners to move beyond isolated station analysis and approach TOD implementation through a strategic, network-wide lens.

Overall, the methodology supports evidence-based urban planning and design by translating complex geospatial data into actionable insights. It not only highlights the strengths and deficiencies of each station area but also provides a foundation for prioritizing investment and guiding urban interventions.

Crucially, the framework balances local specificity with international comparability. While grounded in the unique spatial, institutional, and infrastructural conditions of Tehran, it remains consistent with globally recognized TOD principles. This dual orientation ensures that the findings are both practically relevant for Tehran and aligned with best practices in transit-oriented planning worldwide.

3.3.1 **Catchment Area Definition and Spatial Boundaries**

An essential component of Transit-Oriented Development (TOD) evaluation is the definition of catchment areas - the walkable zones around metro stations that represent the spatial extent of their influence on surrounding land use and mobility behavior. Proper delineation of these areas is critical for analyzing pedestrian accessibility, land use performance, and transit integration, which are all key criteria in TOD assessment.

In this study, a 500-meter walking buffer is used as the primary catchment zone for all metro stations. According to international TOD guidelines - such as the ITDP TOD Standard (2017) - the recommended pedestrian catchment radius typically ranges from 400 to 800 meters, depending on local conditions, urban density, and walking environment. However, in the context of Tehran, particularly in the central districts where metro stations are located very close to each other, using larger buffers (e.g., 800 meters) leads to excessive spatial overlap, distorting TOD scoring and double-counting land use features.

To balance international best practices with Tehran's urban morphology, this research adopts a 500-meter buffer, which falls at the midpoint of the global range. This distance has also been validated in several Iranian studies, including Mirmoghtadaee & Abdi (2021), who argue that 500 meters represents an optimal trade-off between coverage, walkability, and spatial accuracy in TOD-related research in Tehran and other dense Iranian cities.

To further address catchment area overlaps, especially in central Tehran, the study implements spatial clustering to group closely located stations with significant buffer overlap into a single analytical unit. This prevents distortion of accessibility metrics and avoids redundancy in TOD indicator calculations.

The clustering approach includes the following steps:

1. Identifying overlapping station buffers and forming logical clusters based on proximity and urban context.
2. Treating each cluster as a single TOD evaluation unit, enabling a more realistic representation of the station's influence zone.
3. Calculating TOD indicators for each cluster, rather than for overlapping individual stations, to improve analytical clarity and reduce spatial duplication.

This method ensures a more precise and functionally meaningful TOD evaluation, while also supporting the selection of representative case study stations from within well-defined spatial units.

Justification for the Catchment Approach

The selection of a 500-meter walking radius as the standard catchment area in this study is informed by both global best practices and context-specific considerations for Tehran.

In the context of Tehran, several factors support the choice of 500 meters as the most appropriate compromise:

1. **Walking Time and User Comfort:** A 500-meter distance corresponds to an average 5–7-minute walk, which is widely recognized in both international (Cervero & Guerra, 2011) and Iranian (Mirmoghtadaee & Abdi, 2021) TOD literature as a comfortable and acceptable walking distance for most users. This is particularly important in a city like Tehran, where climatic conditions (hot summers, air pollution) and urban design challenges (lack of shading, poor sidewalk maintenance) can discourage longer walks.
2. **Station Proximity and Overlap:** In central Tehran, metro stations are often spaced less than 1 kilometer apart. Using larger buffers (e.g., 800 meters) in such areas leads to significant spatial overlap, where multiple stations appear to serve the same urban territory. This not only inflates accessibility measurements but also results in redundant indicator calculations, undermining the accuracy and distinctiveness of TOD performance scoring. The 500-meter buffer helps minimize overlap, preserving the individuality of each station's influence area while still capturing a realistic walking zone.
3. **Real-World Pedestrian Behavior and Infrastructure Gaps:** Despite its dense urban form, many areas of Tehran lack continuous, high-quality pedestrian infrastructure. Sidewalks are often narrow, uneven, or obstructed, and intersection design frequently prioritizes vehicle flow over pedestrian safety. In such conditions, a 500-meter walking distance is often the functional limit of pedestrian reach, especially for vulnerable groups such as the elderly or people with disabilities. Beyond this range, the likelihood of commuters relying on motorized feeder modes (e.g., taxis, shared rides, minibuses) increases significantly.
4. **Consistency with Local Academic and Policy Research:** Several Iranian urban planning studies have already adopted the 500-meter buffer as a standard TOD catchment, including work by Mirmoghtadaee and Abdi (2021), who argue that this

distance better aligns with the scale and design of Iranian neighborhoods, especially in large cities like Tehran. Additionally, Tehran's National TOD Guideline (2020) does not mandate a fixed buffer, allowing flexibility to accommodate urban form and planning logic - making the 500-meter buffer a defendable methodological choice.

5. **Balance Between Data Sensitivity and Spatial Resolution:** From a technical standpoint, selecting a smaller buffer (e.g., 400m) could lead to insufficient data coverage, especially in low-density or peripheral stations. Conversely, larger buffers (e.g., 800m) would blur distinctions between station areas and reduce the spatial sensitivity of the analysis. The 500-meter threshold offers a methodological balance - large enough to capture essential urban dynamics, yet precise enough to maintain spatial granularity and analytical clarity.

In summary, the 500-meter buffer is not arbitrarily chosen, but is instead a contextually justified distance that balances international standards, Tehran’s urban characteristics, and pedestrian behavior patterns. It enables meaningful TOD evaluation by aligning the scope of spatial analysis with the actual conditions under which commuters interact with the metro system.

3.4 GIS-Based Analytical Techniques

This research employs a range of GIS-based analytical tools in ArcGIS Pro to evaluate the Transit-Oriented Development (TOD) potential of Tehran’s metro station areas. By integrating geospatial analysis with multi-criteria evaluation, the study measures urban performance through the lens of the 5D TOD framework, which consists of Density, Diversity, Design, Destination Accessibility, and Distance to Transit.

Each indicator in the framework is calculated using spatial datasets processed and analyzed with ArcGIS Pro, which enables high-precision mapping, spatial statistics, and advanced modeling.

Tool Name	Tool in ArcGIS Pro	Purpose	Importance in TOD Evaluation
Buffer Tool (Catchment Analysis)	Buffer (Analysis Toolbox)	Create 500-meter pedestrian catchment around each metro station	Defines the TOD influence area; standard buffer for walkability and spatial indicator extraction
Spatial Join	Spatial Join (Analysis Tools → Overlay)	Link demographic, land use, and service data to each buffer	Associates non-spatial attributes to spatial zones, enabling integrated indicator analysis
Intersect & Clip Tools	Intersect, Clip (Analysis Tools → Overlay)	Extract features (roads, land use, services) within the catchment	Ensures spatial precision in calculating density, diversity, and accessibility indicators
Kernel / Point Density	Kernel Density, Point Density (Spatial Analyst → Density)	Map density of services and facilities (e.g., shops, clinics, amenities)	Supports analysis of service concentration and spatial inequality in accessibility
Calculate Geometry / Field Calculator	Calculate Geometry, Field Calculator	Compute lengths, areas, FAR, percentage coverage of land uses, sidewalks, etc.	Derives key TOD metrics such as FAR, mixed-use ratios, road and sidewalk density
Network Analysis (Optional)	Network Analyst Extension	Model pedestrian routing and transit access paths	Provides accurate walkability and service area measurement based on real network conditions (if available)
Hot Spot Analysis (Getis-Ord Gi*)	Hot Spot Analysis (Spatial Statistics → Mapping Clusters)	Identify statistically significant high or low TOD-performing zones	Highlights TOD spatial performance patterns and priority areas for intervention
Zonal Statistics	Zonal Statistics as Table (Spatial Analyst → Zonal)	Summarize raster or tabular data (e.g., average population density, land use intensity) by buffer	Aggregates indicators across each station zone for comparative spatial analysis and ranking

Table 6 GIS Tools and Analytical Techniques Used in ArcGIS Pro by author

Using these tools in ArcGIS Pro provides several key advantages for the spatial evaluation of Transit-Oriented Development (TOD) potential. First, they ensure a high degree of spatial precision in measuring complex urban phenomena such as land use diversity, pedestrian accessibility, and multimodal integration - factors that are often difficult to assess without geospatial technology. Second, the use of standardized tools and procedures enables a consistent and comparable evaluation across all metro stations in Tehran, allowing planners and researchers to benchmark TOD performance in a systematic way.

Furthermore, the GIS-based analytical environment facilitates evidence-based planning by clearly identifying both high-performing and underperforming station areas. This insight supports more informed decision-making regarding where to prioritize TOD investments, zoning reforms, and urban design interventions. Finally, the integration of visual outputs - including thematic maps, cluster classifications, and hot spot analyses - enhances the communicability of findings. These visualizations are critical for translating technical results into practical knowledge for planners, policymakers, and the public, thereby bridging the gap between spatial analysis and urban governance.

3.4.1 TOD Indicators and Evaluation Framework

A set of spatial indicators was selected and structured according to the five dimensions of the TOD 5D framework:

5D Dimension	Indicators Used
Density	Floor Area Ratio (FAR), Population Density
Diversity	Shannon Index, Entropy Index (Land Use Mix)
Design	Walkability Index, Road Network Connectivity, Sidewalk Coverage
Destination Accessibility	Access to Services (Facility Count and Coverage Area)
Distance to Transit	Proximity to Bus Stops, Taxi Services, First/Last-Mile Connectivity

Table 7 spatial indicators was selected and structured based on 5D model by author

All indicators were computed for 500-meter catchment areas around each of the 124 metro stations. After normalization using Min-Max scaling, indicator weights were calculated using the Entropy Method, emphasizing indicators with greater variability across station areas.

The final composite TOD score for each station was obtained by summing the product of normalized values and entropy-derived weights across all five dimensions.

In the second phase, these scores were used as input for K-Means Clustering, which grouped stations into four clusters reflecting different levels of TOD performance - ranging from high potential to low integration. These clusters provided the basis for selecting eight case study stations.

3.4.2 Integration of GIS Base Maps and Spatial Datasets for TOD Evaluation

To conduct a comprehensive TOD assessment, this study integrates multiple GIS-based spatial datasets and base maps to analyze key urban characteristics around metro stations. These datasets provide critical insights into land use patterns, population density, street network connectivity, and multimodal transport accessibility, all of which are fundamental to measuring TOD effectiveness and readiness in Tehran.

By leveraging GIS tools, this research systematically evaluates urban form, transport infrastructure, and accessibility conditions, ensuring that TOD potential is analyzed with spatial accuracy and real-world applicability. The primary GIS datasets used in this study include (Fidar Urban and Architecture Consulting Group, 2023):

- **Land Use Maps: Understanding Functional Diversity Around Metro Stations**

Land use maps play a crucial role in defining the spatial characteristics of TOD zones by classifying urban areas into residential, commercial, mixed-use, and public spaces. These maps help assess whether the land use composition surrounding metro stations supports TOD principles such as high-density, mixed-use, and pedestrian-friendly environments.

By applying Shannon and Entropy indices, the study measures land use diversity to determine how well different urban functions are integrated. Higher land use diversity ensures that residents and commuters have easy access to jobs, services, and amenities within a walkable distance from transit stations.

Additionally, land use maps are analyzed to identify whether transit-adjacent areas support compact development. A well-planned TOD area should minimize urban sprawl, concentrate population density near transit hubs, and reduce car dependency by ensuring that daily needs are met within a short travel radius. Finally, the integration of land use maps with transit infrastructure data helps evaluate how well different land use categories align with metro station locations, ensuring seamless connectivity between transit services and urban development.

- **Building Density Maps: Assessing Population Distribution and Urban Compactness**

Building density maps provide a quantitative assessment of urban compaction, offering insights into how densely built environments contribute to TOD success. By analyzing population density within station catchment areas, the study evaluates whether transit zones are sufficiently populated to sustain high metro ridership.

The Floor Area Ratio (FAR) and building height distribution are also examined as indicators of urban compaction. Higher FAR values indicate vertical growth and efficient land use, which are essential for high-density, transit-supportive environments. In contrast, low FAR values suggest underutilized spaces that may require densification strategies to enhance TOD potential.

Additionally, the study identifies low-density transit zones where urban densification could be strategically implemented to increase housing supply, commercial activity, and transit demand. This helps urban planners prioritize areas for future TOD investments by targeting underdeveloped metro stations that have the potential for high-density, transit-oriented development.

- ❖ **Road Network and Street Connectivity Maps: Evaluating Accessibility and Multimodal Integration**

The design and efficiency of the street network significantly impact walkability, multimodal connectivity, and overall TOD functionality. Analyzing road networks using GIS allows for a detailed examination of how well metro stations are integrated with pedestrian infrastructure and urban transport systems.

One of the key factors assessed in this study is intersection density and connectivity, which directly influence walkability. A higher intersection density typically correlates with a more pedestrian-friendlier environment, as it offers more route choices, shorter travel distances, and reduced vehicle dominance.

The street hierarchy and traffic flow are also analyzed to understand their impact on pedestrian movement and transit access. Wide highways and high-speed roads near metro stations often act as barriers to pedestrian movement, discouraging walkability and reducing transit accessibility. Identifying these barriers allows planners to recommend solutions such as pedestrian bridges, traffic calming measures, and improved crosswalk designs to enhance station accessibility.

Additionally, the study evaluates street-level challenges, such as narrow sidewalks, lack of pedestrian crossings, and disconnected roads, which may limit the effectiveness of TOD implementation. By mapping these constraints, urban planners can develop targeted interventions to improve pedestrian mobility around metro stations.

- ❖ **Public Transport Layers: Measuring First/Last-Mile Connectivity to Metro Stations**

The success of TOD depends not only on the built environment and land use diversity but also on the efficiency of multimodal transport integration. Public transport layers in GIS allow for a detailed analysis of how well metro stations are connected to other transit modes, ensuring that passengers can seamlessly transition between different transport options.

One of the key aspects of this analysis is bus route distribution and accessibility. Well-integrated bus routes can significantly extend the effective catchment area of metro stations, allowing passengers from more distant neighborhoods to easily access high-capacity transit services. By mapping bus stop locations and frequency, this study evaluates whether existing bus services effectively support metro accessibility or if additional feeder services are needed. Similarly, taxi zones and multimodal transfer points are analyzed to understand their role in first/last-mile connectivity. In many urban areas, taxis and ridesharing services serve as critical transit links for passengers traveling beyond standard walking distances. GIS analysis helps determine whether the spatial distribution of these services aligns with metro station locations and whether there are gaps in feeder transit coverage.

By integrating public transport data with land use and road network maps, the study identifies potential weaknesses in multimodal connectivity and proposes solutions for enhancing seamless transit access. The findings will help inform transport policy recommendations, station redesign strategies, and urban planning interventions to optimize TOD performance.

3.5 Stratified Purposive Sampling Method for Case Study Selection

For the selection of representative metro stations for detailed TOD analysis, this study employs a Stratified Purposive Sampling method. This approach is particularly useful when studying a heterogeneous population, such as metro stations with varying TOD performance levels, land use characteristics, and urban connectivity conditions.

Stratified Purposive Sampling is a **combination of two sampling techniques**:

- Stratified Sampling: Divides the population (metro stations) into distinct categories (strata) based on shared characteristics. This ensures that all relevant groups are adequately represented in the sample.
- Purposive Sampling: Involves deliberately selecting specific cases based on their relevance to the research objectives, rather than relying on random selection. This ensures that each selected metro station provides meaningful insights into TOD performance.

The combination of these methods allows for a comprehensive and comparative evaluation of TOD challenges and opportunities in Tehran's metro system.

To achieve a balanced and representative sample, metro stations were categorized based on their TOD performance scores and spatial characteristics. The selection was made to cover a diverse range of conditions, ensuring that both high-performing and low-performing stations were analyzed alongside those facing unique urban challenges.

The first category consists of successful TOD stations, which are those with the highest TOD scores. These metro stations exhibit strong public transport integration, high land use efficiency, and excellent walkability. They serve as best-practice models that demonstrate how TOD principles can be successfully implemented in Tehran. By studying these stations, the research aims to identify the key factors contributing to TOD success, such as well-planned pedestrian infrastructure, mixed-use developments, and efficient multimodal connectivity. These stations also provide a benchmark for TOD planning, allowing planners to replicate successful design elements in other locations.

The second category includes underperforming TOD stations, which have the lowest TOD scores. These stations suffer from poor transit accessibility, low-density development, and weak pedestrian infrastructure. They often lack proper urban integration, resulting in low ridership and heavy car dependency. The selection of these stations is crucial for understanding the primary barriers to TOD implementation in Tehran. By identifying the limitations of these areas - such as disconnected street networks, inadequate transit services, or car-dominated urban design - the study can propose targeted interventions to improve TOD performance in similar locations.

The third category focuses on stations with land use conflicts, where the surrounding areas have high land use diversity but suffer from poor urban design and functional conflicts. These stations are located in areas where residential, commercial, and office spaces coexist, but without a cohesive planning strategy, leading to traffic congestion, pedestrian-vehicle conflicts, and inconsistent zoning regulations. The presence of mixed land uses is a positive TOD feature, but when integration between transport and urban form is poorly managed, the benefits of diversity are lost. By selecting these stations, the research aims to explore how uncoordinated land use planning can create challenges for TOD effectiveness and how policy adjustments can optimize mixed-use environments around transit hubs.

The fourth category consists of underdeveloped TOD stations, which are located in low-density or peripheral urban areas where TOD potential has not yet been activated. These stations often lack the necessary infrastructure, transit-supportive zoning policies, and investment required to develop into high-functioning TOD hubs. The importance of selecting these stations lies in the need to identify the obstacles preventing TOD expansion in areas with lower urban density. Understanding these barriers - such as insufficient public transport services, weak pedestrian networks, and a lack of commercial activity - helps in formulating long-term strategies to promote TOD growth and urban development in these areas.

Why These Four Categories Were Chosen?

The selection of these four TOD categories was designed to ensure a comprehensive and structured assessment of transit-oriented development in Tehran. By analyzing high-performing, low-performing, and uniquely challenged metro stations, the study captures a full spectrum of TOD conditions and provides a comparative framework for evaluating TOD effectiveness. This classification also facilitates the development of targeted policy recommendations, as each category highlights different TOD planning needs.

Including successful TOD stations allows for the identification of best practices and replicable success factors, while the underperforming stations reveal systemic weaknesses in transit accessibility and urban planning. The stations with land use conflicts illustrate how poor integration between transport and zoning regulations can create inefficiencies, and the underdeveloped TOD stations demonstrate how TOD expansion can be supported in emerging urban areas.

This categorization provides a balanced research approach, ensuring that TOD assessment is not limited to high-functioning areas but instead covers both strengths and weaknesses in TOD implementation across different urban contexts in Tehran. The findings from this stratified purposive sampling process will contribute to more effective TOD planning strategies, targeted urban policy recommendations, and improved metro accessibility across the city.

Chapter 4

Assessment of TOD Spatial Indicators and Strategic Station Typology in Tehran

4.1 Evaluation of TOD Indicators Based on the 5D Conceptual Framework

To assess the performance of Transit-Oriented Development (TOD) around metro stations in Tehran, the study adopted the well-established five-dimensional (5D) conceptual framework. This framework captures the key built-environment dimensions that influence transit use and urban livability: Density, Diversity, Design, Destination Accessibility, and Distance to Transit (Cervero & Kockelman, 1997; Ewing & Cervero, 2010). Each of these dimensions was represented by measurable spatial indicators, including Floor Area Ratio (FAR), population density, Shannon and Entropy indices (for land-use mix), walkability index, sidewalk coverage, and road network connectivity.

Given the central focus of this research on land use challenges and strategies surrounding metro stations, the analysis was structured around the core 3D dimensions - Density, Diversity, and Design. Accordingly, to reflect the theoretical and practical significance of each group, a weighted emphasis of 70% was assigned to the 3D indicators, while the remaining 30% was allocated to the 2D indicators (Destination and Distance to Transit). This decision was based on findings from national studies indicating that, in Iranian urban contexts such as Tehran, deficiencies in land use patterns play a more decisive role in undermining TOD effectiveness than transit infrastructure availability (Azari et al., 2017; Kia & Nikzad, 2018).

Indicator Weighting Procedure

To derive the final weights of the indicators, the **Entropy Method** was employed as an objective, data-driven technique. This method evaluates the degree of variability and information provided by each indicator across all stations. Indicators that exhibited greater variability and discriminatory power were assigned higher weights.

First, the raw indicator values were normalized to obtain the proportion pij , where:

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}$$

After normalizing the indicator values, the initial entropy weight for each indicator was computed using the following formula:

$$e_j = -k \sum_{i=1}^{m} p_{ij} \ln(p_{ij}), \quad \text{where } k = \frac{1}{\ln(m)}$$

In this equation, m is the number of stations, and xij is the value of indicator j for station i. The entropy ej reflects the degree of disorder or uniformity in the distribution of indicator j.

The diversity value dj was obtained by:

$$d_j = 1 - e_j$$

and the initial entropy-based weight of each indicator was:

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j}$$

This ensures that all weights sum to 1 and that higher weight is given to indicators with more informational value.

Subsequently, the indicators were grouped into two main categories:

1. Indicators corresponding to the 3D dimensions
2. Indicators corresponding to the 2D dimensions

Within each group, the entropy-derived weights were normalized so that their total equaled 1. To integrate the conceptual weight structure of the study, the normalized weights were then scaled by **0.7 for 3D** and **0.3 for 2D**, respectively:

$$w_j^{\text{final}} = W_{\text{group}} \times \left(\frac{w_j}{\sum w_j \text{ (within group)}} \right)$$

Where W_{group} is either 0.7 (for 3D) or 0.3 (for 2D). This process ensured that each indicator received its final weight as a proportion of the total model weight, in a way that maintains both data sensitivity and conceptual alignment with the study's objective.

Finally, the composite TOD score for each station was calculated as a weighted sum of the normalized indicator values:

$$\text{iTOD Score}_i = \sum_{j=1}^{n} w_j^{\text{final}} \cdot x_{ij}$$

Where x_{ij} is the normalized value of indicator j for station i, and $w_j$final is the final rescaled weight of that indicator.

Dimension	Indicator	Entropy Weight		Rescaled Weight (70/30)	Weighting Formula
DIVERSITY	Shannon	0.024	70%	0.028	Shannon * 0.028
	Entropy	0.014		0.016	Entropy * 0.016
DENSITY	Population	0.115		0.131	Pop density * 0.131
	Far	0.056		0.064	Far * 0.064
DESIGN	Walkability index	0.281		0.320	Walkability * 0.320
	Road network connectivity	0.067		0.076	Connectivity * 0.076
	Sidewalk coverage	0.057		0.066	Sidewalk coverage * 0.066
DESTINATION	Accessibility to Services	0.246	30%	0.191	Accessibility * 0.191
	Service area	0.079		0.061	Service area * 0.061
DISTANCE	Multimodal connectivity	0.013		0.010	Multimodal * 0.010
	Last Mile to POI	0.049		0.038	Last mile * 0.038

Table 8 Indicator Weighting Structure Using Entropy Method and Conceptual Rescaling (70/30) by author

Overall, the Transit-Oriented Development (TOD) indicator weighting in this study was conducted through a dual-layered method that integrates objective entropy-based weighting with a conceptually informed 70/30 dimension-level structure. This approach ensures a balance between statistical accuracy and theoretical relevance, supporting the overall research objective of evaluating TOD land-use performance across Tehran's metro stations.

In the first stage, the Entropy Weighting Method was applied to normalized values of all indicators. This allowed for a data-driven assessment of each indicator's informational contribution and variability across stations. Indicators with higher discriminatory power - such as Walkability Index and Accessibility to Services - received higher entropy weights, while less variable indicators - such as Multimodal Connectivity - received lower weights.

In the second stage, indicators were grouped into two conceptual categories:

- **3D dimensions (Density, Diversity, Design), reflecting land-use structure**
- **2D dimensions (Destination Accessibility and Distance to Transit), reflecting mobility and service access**

To align the weighting model with the research's strategic focus on land-use performance, entropy weights were normalized within each group so that the sum of weights equaled 1. The resulting weights were then adjusted according to a 70% emphasis on 3D indicators and 30% on 2D indicators. This prioritization is supported by Iranian studies (Azari et al., 2017; Kia &

Nikzad, 2018), which highlight that in Tehran and similar urban contexts, deficiencies in land use configuration play a more critical role in undermining TOD effectiveness than transit supply alone.

As a result, each indicator received a final weight that captures both its empirical variability and its strategic importance within the TOD framework. For instance:

- The Walkability Index received the highest weight (0.320), reflecting its strong spatial variability and its foundational role in pedestrian-based TOD.
- Accessibility to Services (0.191) received the highest weight among transport-related indicators, underscoring its importance in supporting functional land use.
- In contrast, Multimodal Connectivity (0.010) was weighted lower due to its minimal variation across stations.

These final weights were then used to compute a composite TOD score for each metro station by multiplying each normalized indicator by its respective weight. This composite score acts as the quantitative backbone of all subsequent spatial analyses in the study, including *K-Means clustering, Hot Spot (Gi) detection*, and the selection of representative case study stations.

Overall, the selected weighting strategy enables a robust, interpretable, and policy-relevant understanding of TOD performance across Tehran. It allows for meaningful comparisons between stations and provides a solid analytical foundation for developing context-sensitive and responsive land-use strategies in transit-oriented planning.

4.2 Spatial Pattern Analysis and TOD Mapping

In order to gain a deeper understanding of how TOD-related characteristics are distributed across Tehran's metro network, a multi-step spatial analysis was conducted using GIS. This section presents the spatial variation of TOD indicators, followed by hotspot analysis.

4.2.1 Spatial Distribution of TOD Indicators

Each TOD indicator was mapped using graduated color symbology in GIS to visualize its geographic distribution. This included indicators such as population density, Floor Area Ratio (FAR), land-use mix (Shannon and Entropy indices), walkability, sidewalk coverage, and access to services.

These maps revealed several important patterns:

- Density indicators (FAR, population) peaked in central and mid-southern districts, particularly among older urban corridors.
- Diversity indicators showed higher land-use mix near inner-city stations, while peripheral areas often exhibited monocentric or functionally segregated land use.

- Design indicators (walkability, road network connectivity) were stronger in districts with finer street grids and continuous pedestrian networks.
- Accessibility indicators highlighted service-rich centers versus under-served peripheries, particularly in the east and southwest.

These spatial layers clarified the functional performance of each metro station's surroundings in relation to TOD principles and provided a diagnostic view of spatial inequality across the network.

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Tehran Urban & Suburban Railway Company (METRO)

Geospatial Representation of Tehran Population Density in Buffer Zone

POPULATION DENSITY HEATMAP

Sparse

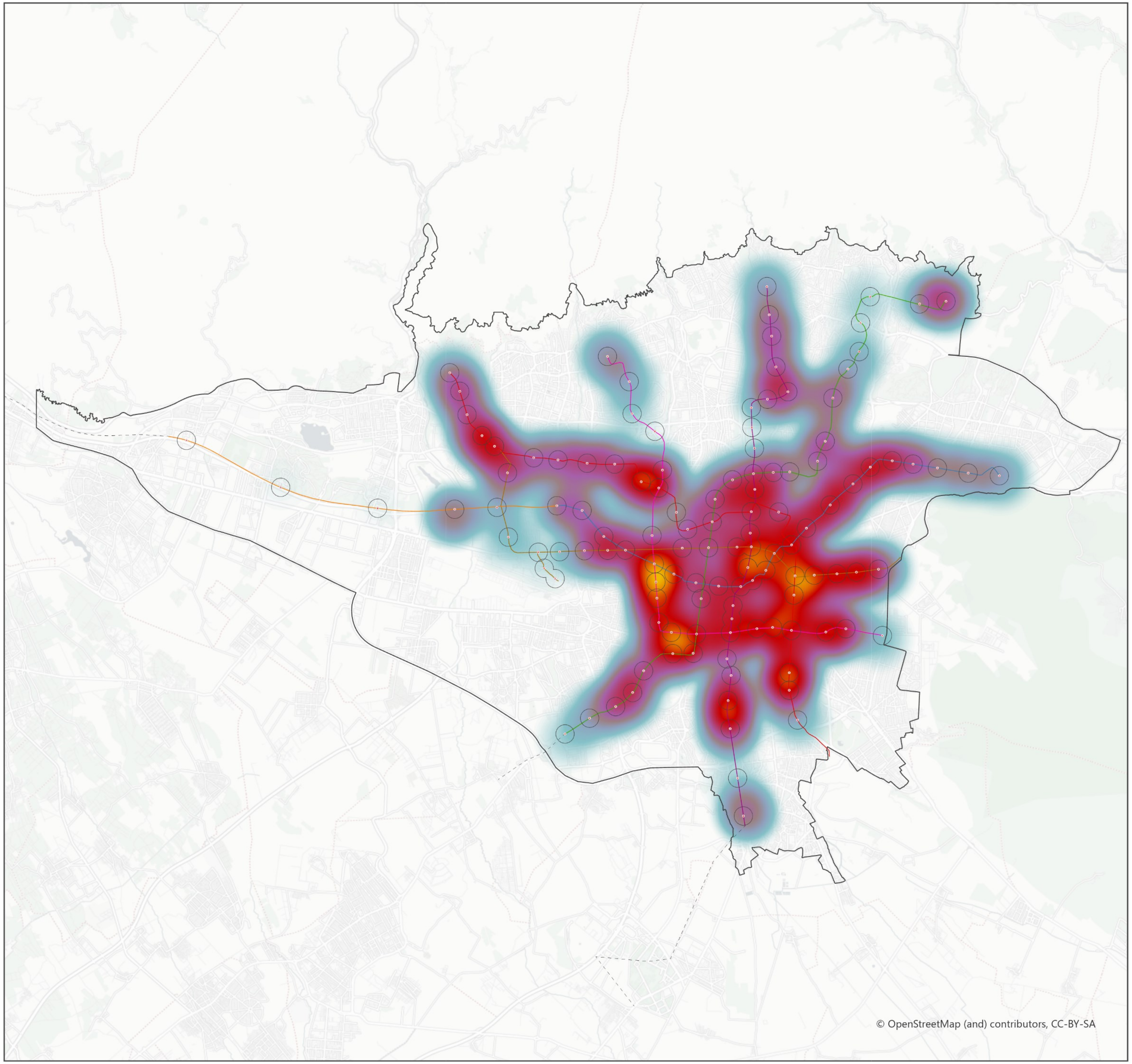
Dense

Metro Station
Line 1
Line 2
Line 3
Line 4
Line 5
Line 6
Line 7
Lines (beyond city limits)
Buffer Zone
Tehran Boundary

BaseMap: OpenStreetMap

N

0 3.5 7 14 Kilometers



Map 8
This map created by the author

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Geospatial Representation of Tehran Building Density in Buffer Zone

FAR HEATMAP
(floor area ratio)

Sparse

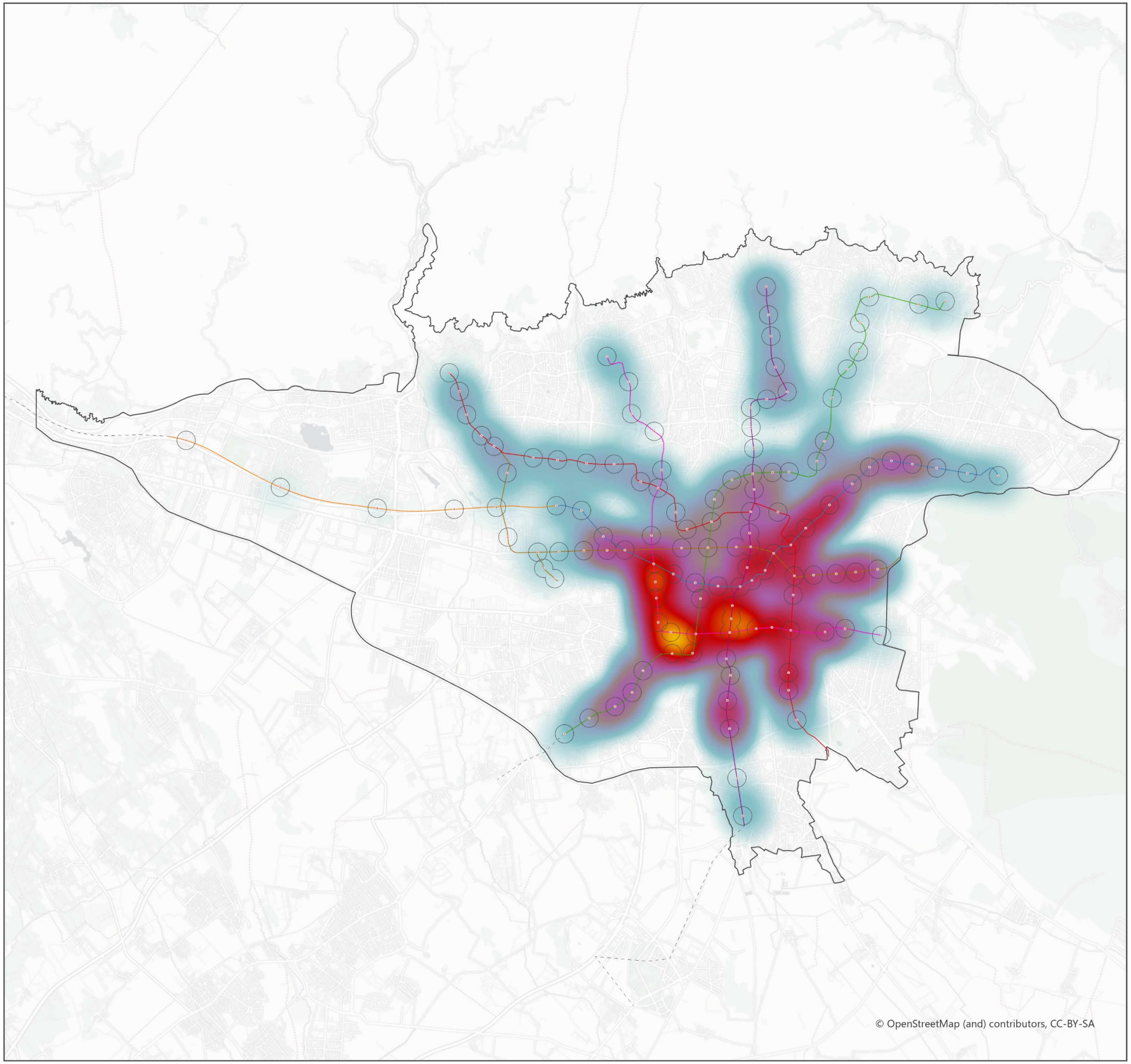
Dense

- Metro Station
- Line 1
- Line 2
- Line 3
- Line 4
- Line 5
- Line 6
- Line 7
- Lines (beyond city limits)
- Buffer Zone
- Tehran Boundary

BaseMap: OpenStreetMap

N

0 3.5 7 14 Kilometers



Map 9
This map created by the author

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Tehran Urban & Suburban Railway Company (METRO)

Geospatial Representation of Tehran Landuse diversity and the evenness of distribution in Buffer Zone

SHANNON INDEX

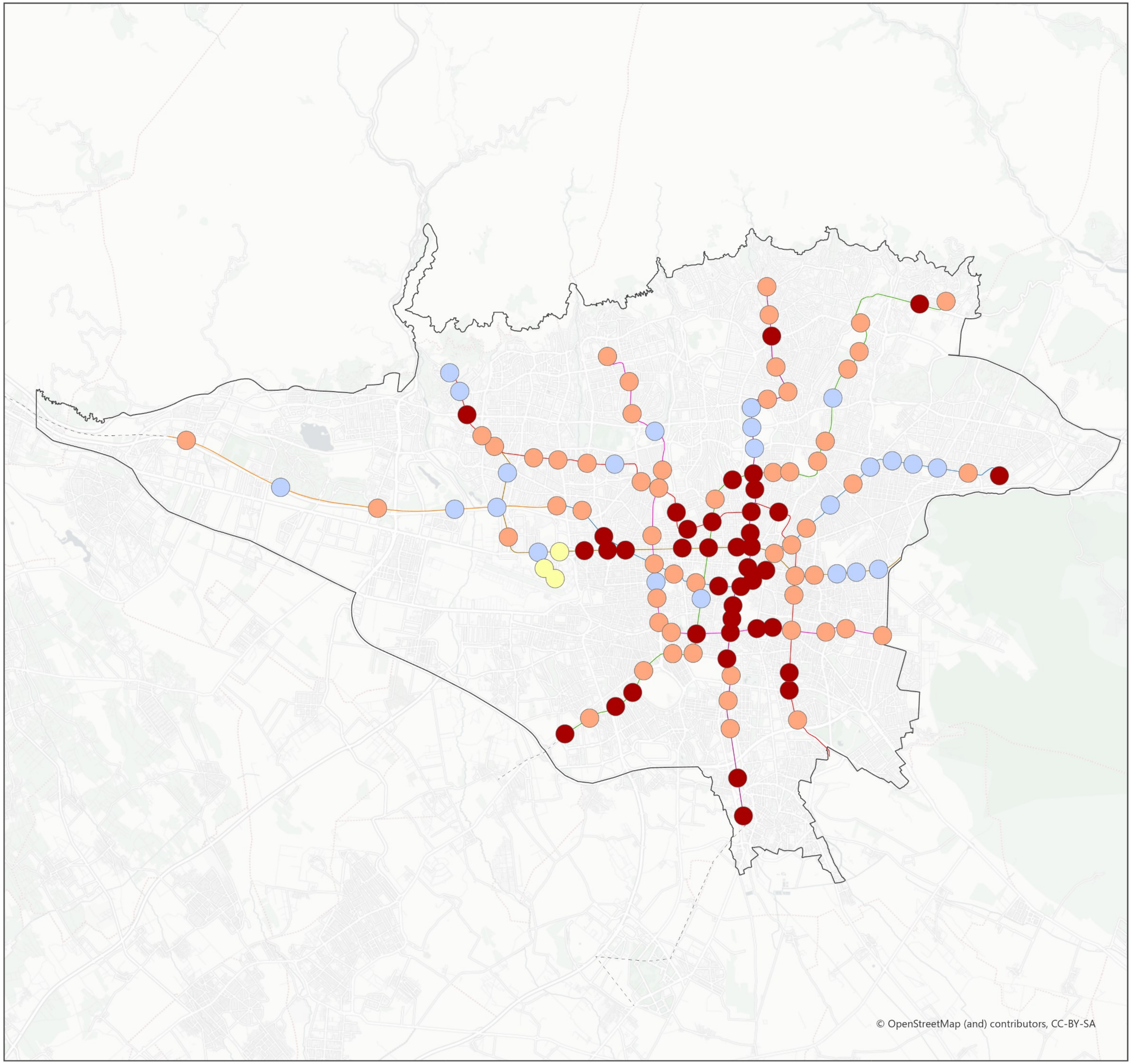
(TOD-friendly land uses)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- Metro Station
- Line 1
- Line 2
- Line 3
- Line 4
- Line 5
- Line 6
- Line 7
- Lines (beyond city limits)
- Buffer Zone
- Tehran Boundary

BaseMap: OpenStreetMap

N

0 3.5 7 14 Kilometers



Map 10

This map created by the author

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Tehran Urban & Suburban Railway Company (METRO)

Geospatial Representation of Tehran Landuse diversity and the evenness of distribution in Buffer Zone

LANDUSE ENTROPY INDEX

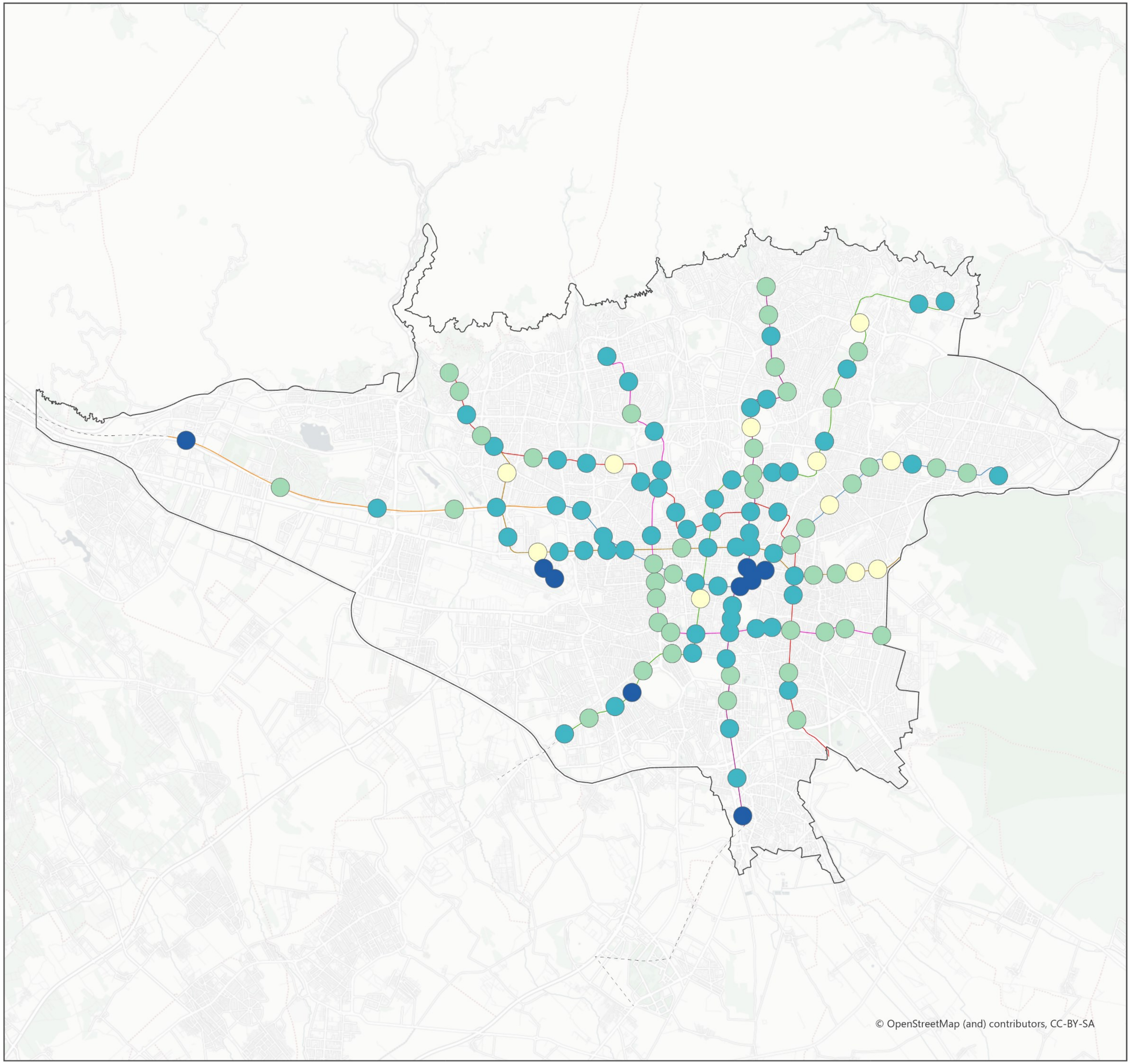
- 0.22 - 0.41
- 0.42 - 0.61
- 0.62 - 0.80
- 0.81 - 1
- Metro Station
- Line 1
- Line 2
- Line 3
- Line 4
- Line 5
- Line 6
- Line 7
- Lines (beyond city limits)
- Buffer Zone
- Tehran Boundary

BaseMap: OpenStreetMap

N

0 3.5 7 14 Kilometers

Map 11
This map created by the author



شرکت راه آهن شهری تهران و حومه (مترو)

Tehran Urban & Suburban Railway Company (METRO)

Geospatial Representation of Tehran Network-based Accessibility to Services in Buffer Zone

SERVICE AREA ACCESSIBILITY INDEX

- Service Area
- Accessibility Network
- Facility (Metro station)
- Line 1
- Line 2
- Line 3
- Line 4
- Line 5
- Line 6
- Line 7
- Lines (beyond city limits)
- Buffer Zone
- Tehran Boundary

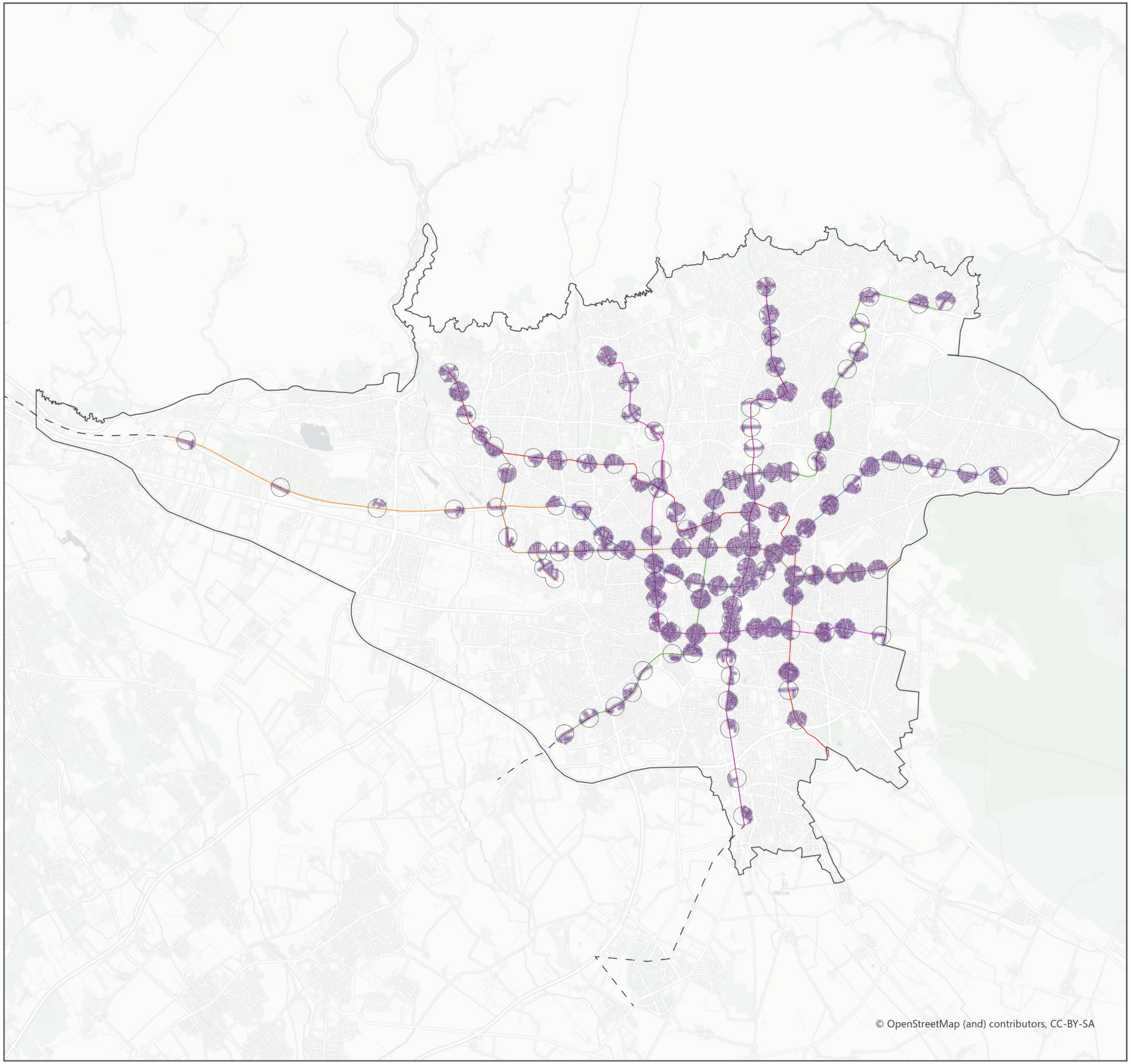
BaseMap: OpenStreetMap

N

0 3.5 7 14 Kilometers

Map 12

This map created by the author



شرکت راه آهن شهری تهران و حومه (مترو)
Tehran Urban & Suburban Railway Company (METRO)

Geospatial Representation of Tehran Number of Service Facilities in Buffer Zone

SERVICE LANDUSE DENSITY

Sparse

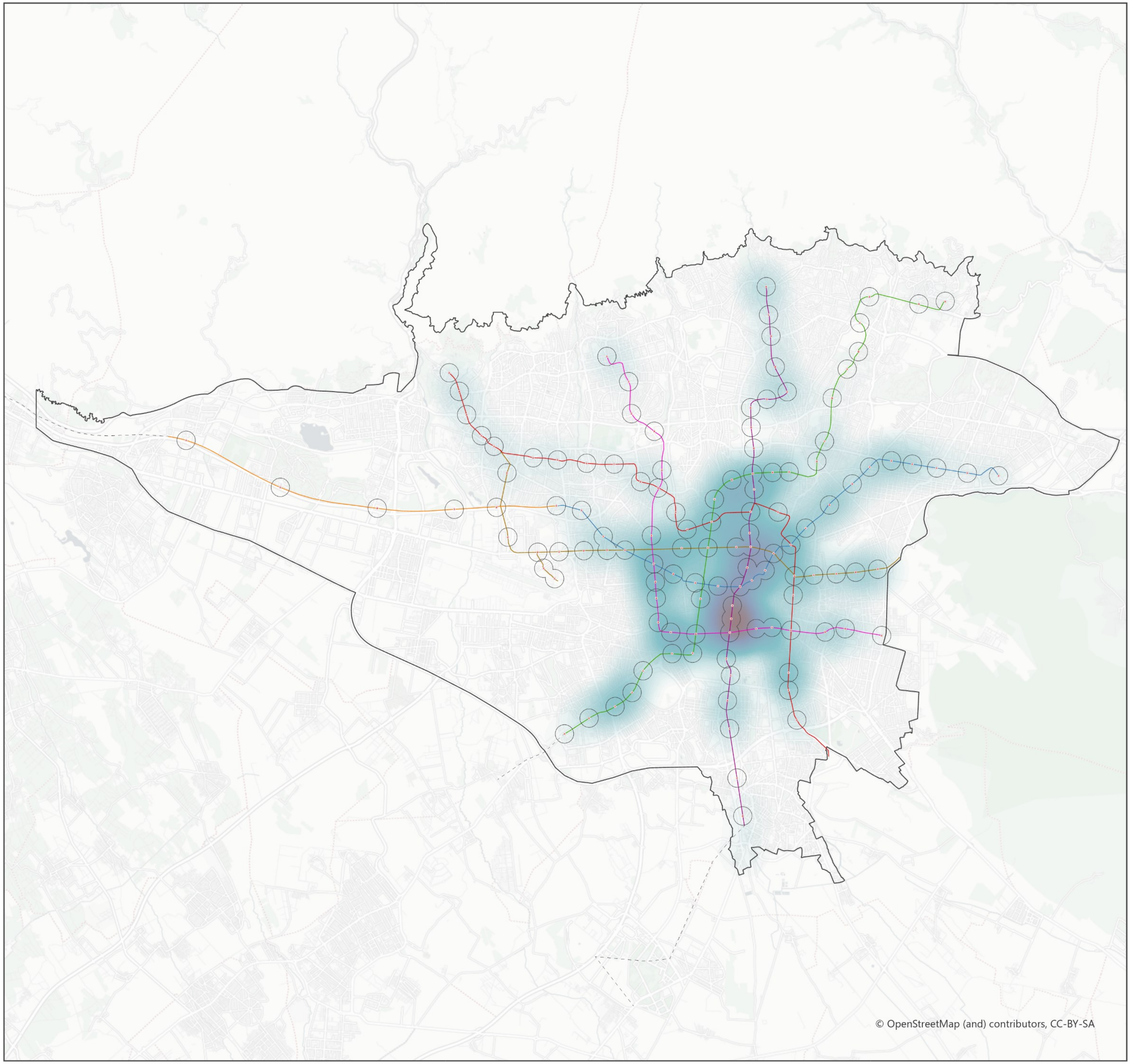
Dense

Metro Station
Line 1
Line 2
Line 3
Line 4
Line 5
Line 6
Line 7
Lines (beyond city limits)
Buffer Zone
Tehran Boundary

BaseMap: OpenStreetMap

N

0 3.5 7 14 Kilometers



Map 13
This map created by the author

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Tehran Urban & Suburban Railway Company (METRO)

Geospatial Representation of Tehran Walkability Index in Buffer Zone

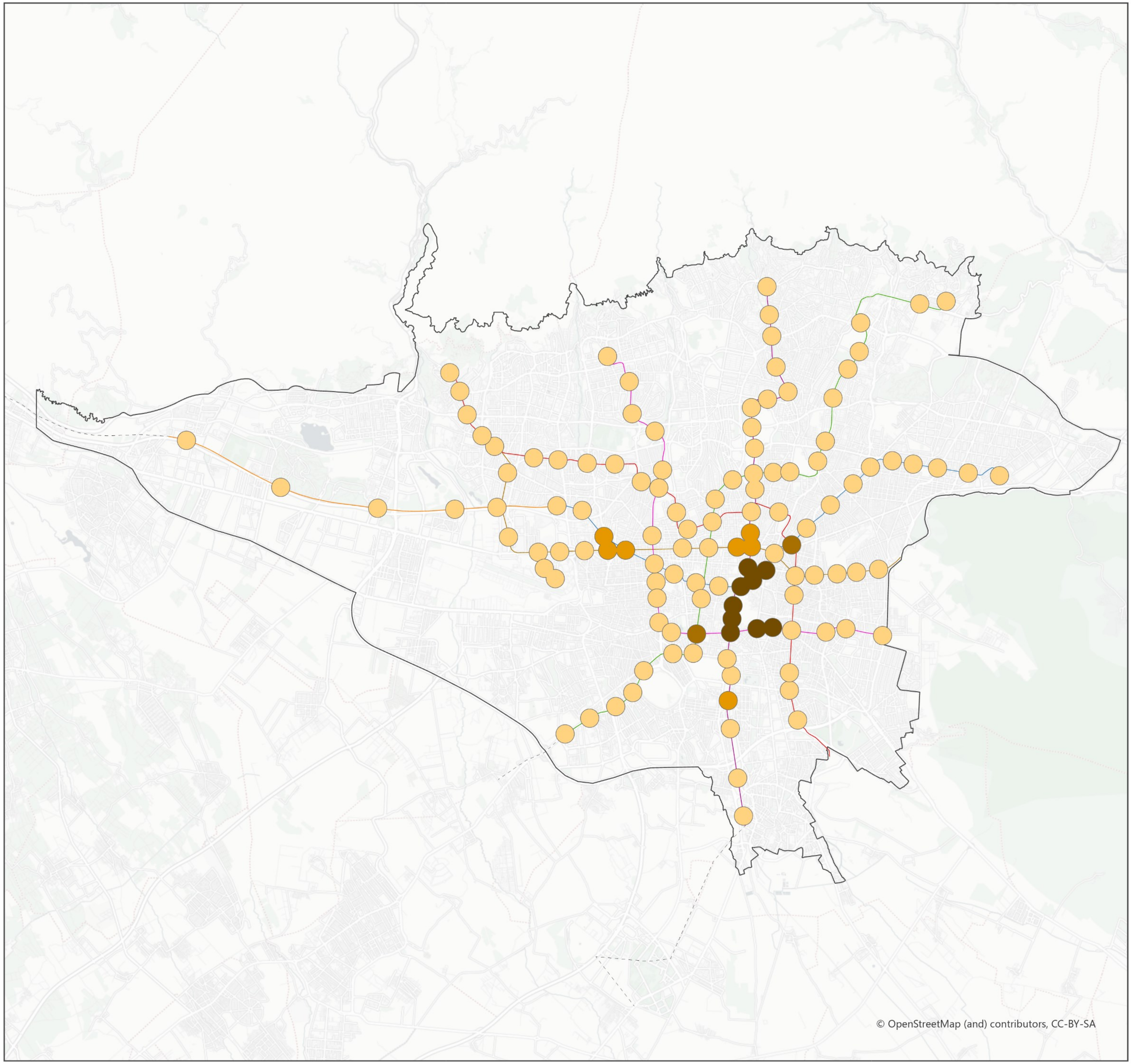
WALKABILITY INDEX

- 0 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1
- Metro Station
- Line 1
- Line 2
- Line 3
- Line 4
- Line 5
- Line 6
- Line 7
- Lines (beyond city limits)
- Buffer Zone
- Tehran Boundary

BaseMap: OpenStreetMap

N

0 3.5 7 14 Kilometers



Map 14
This map created by the author

شرکت راه آهن شهری تهران و حومه (مترو)

Tehran Urban & Suburban Railway Company (METRO)

Geospatial Representation of Tehran Multimodal Connectivity in Buffer Zone

MULTIMODAL CONNECTIVITY

- 0 - 0.41
- 0.41 - 0.56
- 0.56 - 0.74
- 0.74 - 0.88
- Bus Station
- Taxi Line
- Metro Station
- Line 1
- Line 2
- Line 3
- Line 4
- Line 5
- Line 6
- Line 7
- Lines (beyond city limits)
- Buffer Zone
- Tehran Boundary

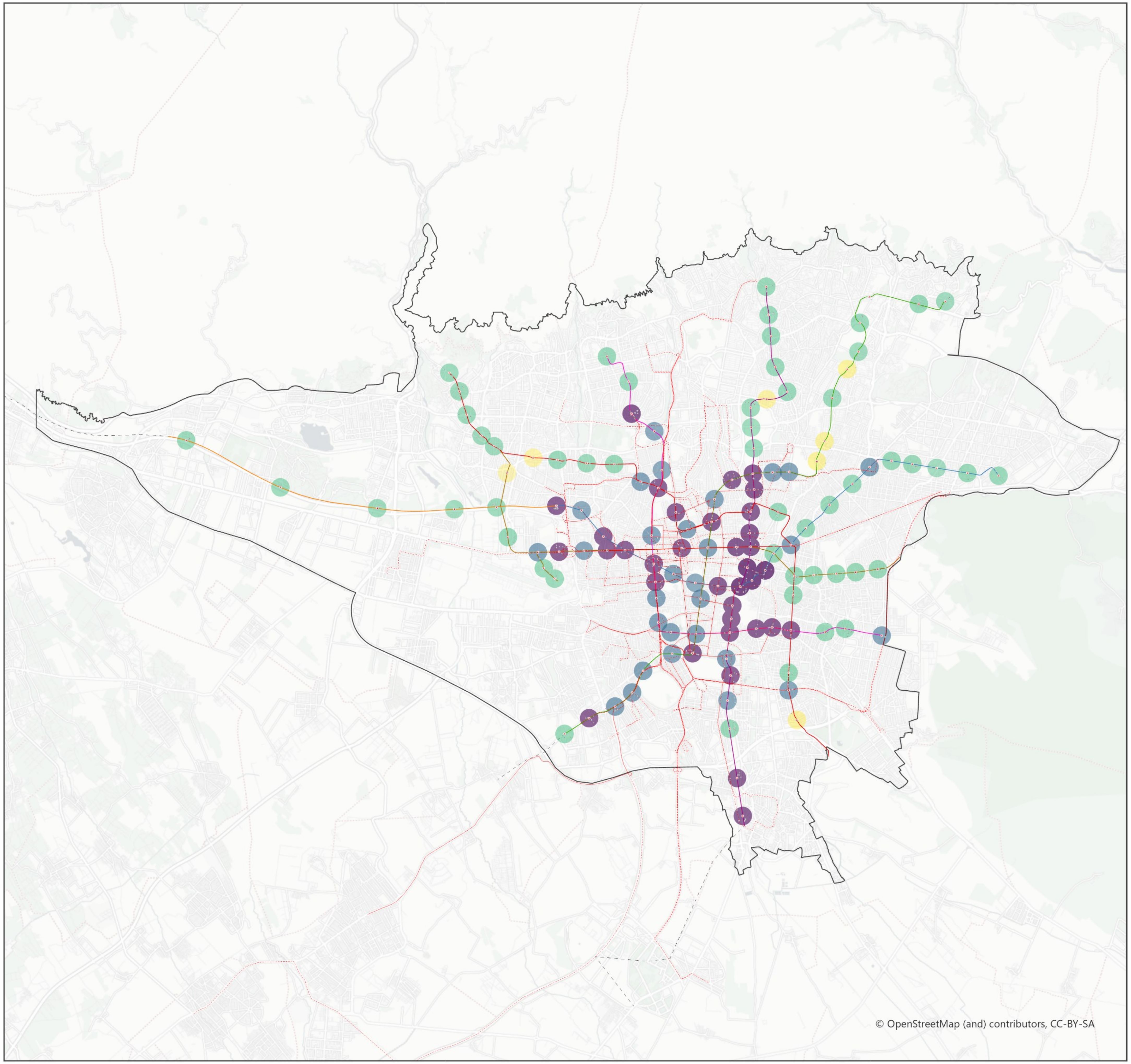
BaseMap: OpenStreetMap

N

0 3.5 7 14 Kilometers

Map 15

This map created by the author



4.2.2 Hot Spot Analysis of TOD Scores (Gi*)

To statistically identify areas with high or low concentrations of TOD performance, Getis-Ord Gi* hotspot analysis was applied to the composite TOD scores. This revealed:

- Significant hot spots in central, inner-south, and west-central zones - often where density, diversity, and design intersected positively
- Cold spots in far eastern and western stations, typically characterized by low land-use mix, sparse density, and poor connectivity
- Non-significant zones spread across mid-level performers, often indicating fragmentation and inconsistent TOD application

Stations were categorized based on confidence intervals (99%, 95%, 90%), enabling clear identification of statistically significant TOD patterns.

4.3 Classification of Metro Stations Based on TOD Performance

This section presents a classification of metro stations based on their performance within the TOD framework. By using the final composite TOD scores, derived from a weighted multi-criteria approach, the analysis aims to offer a systematic understanding of functional disparities across the Tehran metro network. This classification supports the identification of spatial patterns, performance gaps, and strategic opportunities for policy and design intervention. The subsection begins with the results of K-Means clustering and is followed by an integrated interpretation combining statistical and spatial analyses through Hot Spot mapping.

4.3.1 K-Means Clustering Based on Weighted TOD Scores

Using the final composite scores, K-Means clustering was performed to classify metro stations into four typological groups. This clustering emphasized land-use performance (3D indicators), consistent with the study's core objective. The four groups identified were:

1. **Cluster 1: Successful and Balanced TOD Stations**
   High density, strong walkability, good land-use mix
   → Mainly inner-city core and redevelopment zones
2. **Cluster 2: Underperforming Stations**
   Weak in most indicators, especially density and diversity
   → Peripheral, low-investment areas with structural TOD failure

3. **Cluster 3: Functionally Unbalanced Nodes (Land use Conflict)**
   Either overbuilt or under designed areas with imbalanced land-use structures
   → Often around highways or isolated developments
4. **Cluster 4: Underdeveloped TOD Stations (High-Potential but Low-Density Stations)**
   Located in growth corridors with access potential but lacking FAR/population
   → Urban periphery with room for densification

4.3.2 Integrated Interpretation: Hot Spot vs. Cluster Analysis

To develop a more comprehensive and spatially nuanced typology of TOD (Transit-Oriented Development) performance across metro station areas, we conducted a cross-analysis of two key methods:

- *Hot Spot Analysis (Gi*)*, which identifies statistically significant spatial concentrations of high or low TOD scores.
- K-Means Cluster Analysis, which groups stations into clusters based on multi-dimensional TOD performance indicators.

This integrated approach reveals both congruencies and mismatches between data-driven classifications and spatial realities, offering key interpretive insights:

1. Reinforcing TOD Excellence: Cluster 1 & Hot Spots

Many stations in Cluster 1, representing the highest-performing TOD areas, strongly overlap with hot spots in the Gi* analysis. This spatial concurrence validates the robustness of these stations as TOD exemplars. These areas often feature:

- High land use mix,
- Dense and walkable environments,
- Good multimodal integration,
- Proximity to urban centers or key destinations.

This alignment indicates policy effectiveness and urban form consistency, where planning strategies are well-implemented and produce measurable spatial benefits.

2. Unrealized Potential: Cluster 2 in Non-Significant Zones

A significant number of Cluster 2 stations are located in areas where the Gi* statistic indicates no significant spatial pattern - neither hot nor cold spots. These stations typically:

- Perform moderately on TOD metrics,
- Exhibit mixed qualities (e.g., good access but poor land use diversity),
- Exist in transitional or evolving neighborhoods.

Their placement in statistically “neutral” zones suggests untapped spatial potential. With targeted interventions - such as zoning reform, pedestrian infrastructure, or mixed-use incentives - these areas could shift toward high-performing TODs.

3. Underperformance and Spatial Isolation: Cluster 3 & 4 and Cold Spots

Many Cluster 3 and 4 stations - those with low TOD performance - correspond with cold spots in the Gi* map. These typically occur in:

- Peripheral or fragmented urban zones,
- Mono-functional land uses (e.g., industrial or low-density residential),
- Poor last-mile connectivity and pedestrian accessibility.

This spatial alignment reinforces the systemic neglect or marginalization of these areas. Their physical and functional disconnect from the broader urban structure perpetuates a cycle of low performance and low investment.

4. Discrepancies Reveal Planning Gaps and Contextual Mismatches

A critical observation is the mismatch between cluster membership and spatial significance in some cases:

- Stations with favorable TOD scores (e.g., in Cluster 2) may still fall within cold or neutral zones due to poor urban context (e.g., surrounded by highways or gated communities).
- Conversely, stations with relatively weak scores may be in hot spot zones due to proximity to vibrant urban fabrics that remain under-leveraged.

These discrepancies highlight planning inconsistencies, where local station area improvements are undermined by broader urban disconnection or policy inertia. They underscore the need for context-sensitive TOD strategies that go beyond technical scoring and engage with spatial structure and systemic barriers.

Overall, the integrated analysis of hotspot mapping and K-Means clustering provides a nuanced and multi-scalar understanding of TOD performance across Tehran’s metro station areas. By overlaying statistical clusters with spatial Gi* patterns, this approach not only validated high-performing stations (Cluster 1) that also emerged as significant hotspots, but also uncovered latent opportunities and critical deficiencies. For instance, several Cluster 2 stations - moderate performers - fell within statistically neutral zones, suggesting areas with untapped TOD potential that may benefit from targeted urban interventions. Conversely, many of the poorly performing stations in Clusters 3 and 4 aligned with cold spots, reinforcing their structural and spatial marginality, often marked by weak pedestrian networks, mono-functional land uses, or peripheral locations. Importantly, discrepancies between clustering and hotspot results revealed planning inconsistencies, such as high-scoring stations being spatially isolated or low-scoring ones being located near vibrant urban zones but suffering from contextual or policy neglect. Together, this integrated method reveals not just how TOD station areas perform statistically, but why they perform the way they do - highlighting underlying spatial structures, systemic gaps, and opportunities for place-based improvement. As such, it offers a powerful diagnostic tool for urban policymakers and planners seeking to refine TOD strategies in context-sensitive and spatially responsive ways.

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Geospatial Representation of Tehran Clustering based on TOD Scores in Buffer Zone

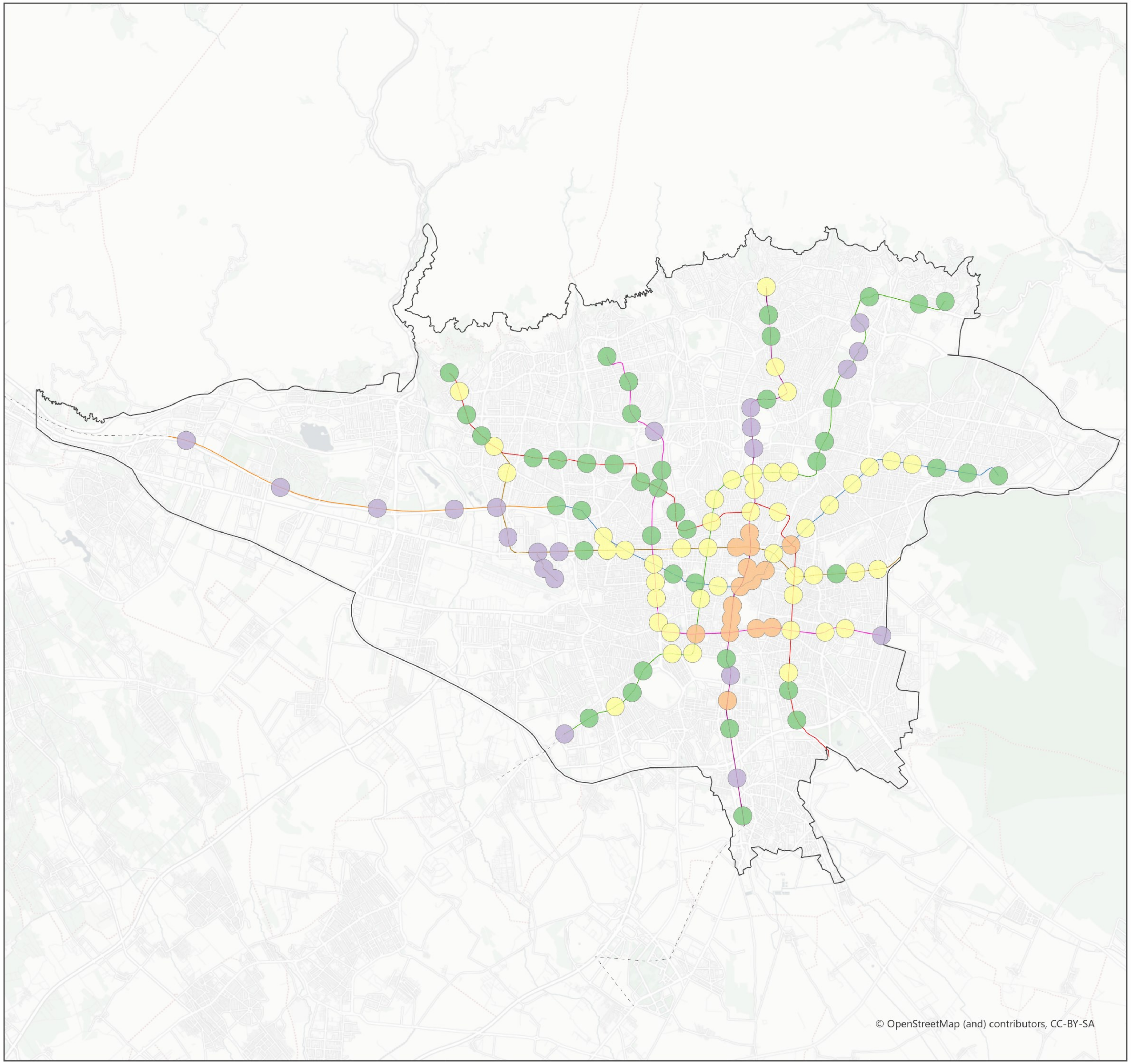
K-MEANS CLUSTERING

- Successful & Balanced TOD Stations
- Underperforming Stations
- Functionally Unbalanced (Landuse Conflict)
- Underdeveloped TOD Stations (high potentional but low density)
- Bus Station
- Taxi Line
- Metro Station
- Line 1
- Line 2
- Line 3
- Line 4
- Line 5
- Line 6
- Line 7
- Lines (beyond city limits)
- Buffer Zone
- Tehran Boundary

BaseMap: OpenStreetMap

N

0 3.5 7 14 Kilometers



Map 16

This map created by the author

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Tehran Urban & Suburban Railway Company (METRO)

Geospatial Representation of Tehran GI HotSpot Analysis in Buffer Zone

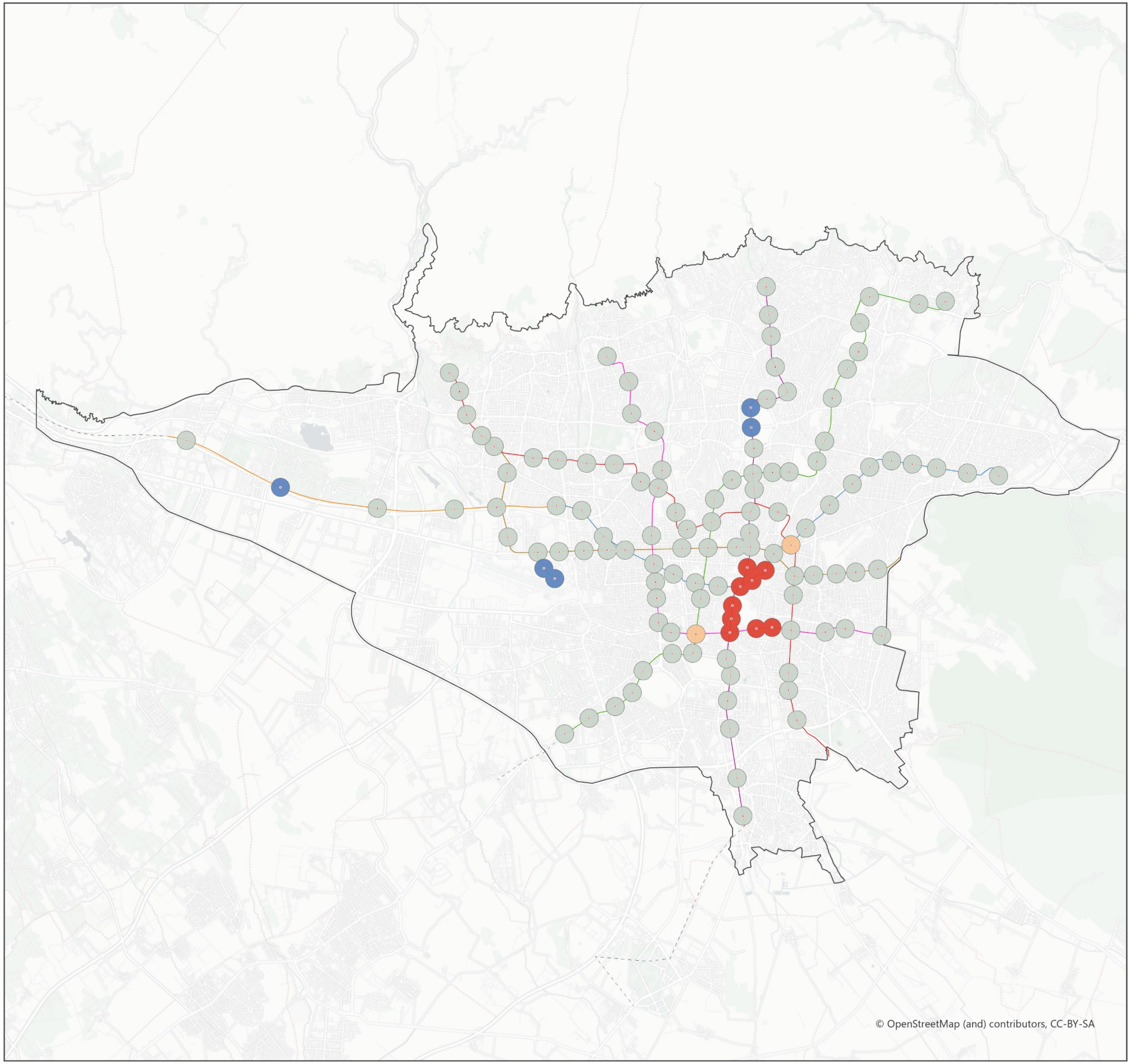
HOTSPOT_GI

- -1- -0.99
- 0 - 1
- 1 - 2
- 2 - 3
- Bus Station
- Taxi Line
- Metro Station
- Line 1
- Line 2
- Line 3
- Line 4
- Line 5
- Line 6
- Line 7
- Lines (beyond city limits)
- Buffer Zone
- Tehran Boundary

BaseMap: OpenStreetMap

N

0 3.5 7 14 Kilometers



Map 17
This map created by the author

4.4 Selection and Introduction of Case Study Stations

To represent the diversity of Transit-Oriented Development (TOD) conditions across Tehran's metro network, eight metro stations were purposefully selected - two from each of the four identified K-Means clusters. This selection strategy was guided by the need to capture both the internal variation within clusters and the contrast across them. For each cluster, one station with the highest TOD score and one with the lowest score was chosen to ensure a balanced perspective on best practices, challenges, and latent potential.

From **Cluster 1** - the highest-performing group - **Mohamadiyeh Station** (first rank) and **Bokharayi Station** (last rank) were selected. Mohamadiyeh exemplifies integrated land use, multimodal access, and high-density development, while Bokharayi illustrates the limits of performance even within a strong cluster, revealing overlooked opportunities and structural weaknesses.

- **Mohamadiyeh Station** *(Highest TOD score)*
  Location: Central Tehran, junction of Metro Lines 1 and 7
  Typology: Urban core / multimodal hub
  Performance: Outstanding TOD metrics - high walkability, integrated transit modes, diverse land uses (residential, commercial, medical, educational). A benchmark for TOD best practices.
- **Bokharayi Station** *(Lowest TOD score)*
  Location: Southern fringe of central Tehran
  Typology: Transitional zone / residential edge
  Performance: While part of a high-performing cluster, this station lags behind due to mono-functional land use, lack of public spaces, and limited pedestrian infrastructure. It reveals the performance range even within the best-performing cluster.

From **Cluster 2**, characterized by moderate but varied performance, **Hosseiniabad Station** and **Hemat Station** were chosen. Hosseiniabad reflects promising TOD features such as land-use mix and walkability, while Hemat displays spatial fragmentation and limited functional integration despite its centrality.

- **Hosseiniabad Station** *(Highest TOD score)*
  Location: Southwest Tehran, along Metro Line 3
  Typology: Mid-density residential district
  Performance: Strong land-use mix, functional pedestrian access, and proximity to

services. The station has TOD potential if supported by vertical integration and local-scale public space interventions.

- **Hemat Station** *(Lowest TOD score in Cluster 2)*
  Location: Western edge of central Tehran
  Typology: Low-density residential zone
  Performance: Characterized by poor integration between transit and surrounding land uses, weak service availability, and limited pedestrian continuity. Represents unfulfilled TOD opportunity in a zone with otherwise favorable location.

For **Cluster 3**, which includes underperforming stations with selective strengths, **Ketab Station** and **Sana'at Station** were included. Ketab, the best in its cluster, benefits from cultural-educational synergy and service diversity, whereas Sana'at represents deep TOD deficits stemming from industrial zoning, weak pedestrian networks, and low residential intensity.

- **Ketab Station** *(Highest TOD score)*
  Location: Western Tehran, Line 7 corridor
  Typology: Educational/cultural cluster
  Performance: Good functional diversity and pedestrian layout, with potential for cultural branding and mixed-use infill. Demonstrates how focused interventions can yield TOD progress in mid-tier areas.
- **Sana'at Station** *(Lowest TOD score in Cluster 3)*
  Location: Industrial belt along Line 7
  Typology: Industrial/office zone
  Performance: Dominated by mono-functional industrial land uses, weak pedestrian connectivity, and negligible residential presence. Represents structural TOD failure but also offers long-term redevelopment opportunities through land-use transformation.

Lastly, from **Cluster 4**, the lowest-performing group with pervasive TOD gaps, **Sabalan Station** and **Kashani Station** were selected. Sabalan shows some land-use diversity and walkable infrastructure, suggesting a foundation for future TOD, whereas Kashani illustrates extreme mono-functionality, poor access, and a lack of supportive urban form.

- **Sabalan Station** *(Highest TOD score)*
  Location: Northeast Tehran, Line 2 corridor

Typology: Residential-commercial mix

Performance: Despite cluster-wide weaknesses, Sabalan offers a relatively balanced land-use structure and walkability elements. It could serve as a prototype for upgrading low-performing TOD zones through fine-grain planning and pedestrian investment.

- **Kashani Station** *(Lowest TOD score in Cluster 4)*

  Location: Peripheral residential area on Line 2

  Typology: Mono-functional residential edge

  Performance: Severely underdeveloped TOD conditions - poor service accessibility, pedestrian barriers, and lack of vibrant urban edges. Represents the extreme end of spatial isolation and transit underperformance.

Each of these stations will be introduced in greater detail in the subsequent sections, including location context, physical and functional typology, and a brief overview of their TOD performance. Together, they provide a holistic sample to critically assess TOD implementation challenges and identify policy-relevant insights across the urban spectrum of Tehran.

Chapter 5

In-Depth Comparative Analysis of Selected Case Studies

5.1 Case Study Design and Methodology

In order to explore spatial variations in Transit-Oriented Development (TOD) performance, a case study was designed involving eight metro stations in Tehran, selected across four clusters derived from K-means spatial classification. Each cluster represents a unique typological group of stations with shared spatial and functional characteristics. Within each cluster, two stations were chosen: one with the highest TOD performance score and one with the lowest. This sampling strategy enables a nuanced and balanced investigation of both successful and underperforming cases within similar urban contexts.

This selection method serves multiple analytical goals:

- **Intra-cluster comparisons**: By comparing the top and bottom performers within each typological cluster, we can identify the specific spatial, functional, and policy-related factors that lead to divergence in TOD outcomes - despite similar urban contexts. This helps isolate internal dynamics such as land-use inefficiencies, poor design interventions, or governance issues that limit TOD success.
- **Inter-cluster synthesis**: By examining the high-performing stations across different clusters, we can explore transferable strengths or best practices. At the same time, low-performing stations across clusters may exhibit common weaknesses (e.g., poor connectivity, monofunctional land use) that signal broader systemic barriers to TOD implementation. This cross-cluster analysis supports more generalized policy recommendations and prioritization strategies.
- **Strategic focus on the weakest station (HEMAT)**: Among the low-performing stations, HEMAT was identified as the weakest overall. It serves as a strategic base case for developing targeted TOD enhancement scenarios. Lessons drawn from better-performing stations can be synthesized into context-sensitive interventions aimed at revitalizing this area.

To support these comparisons and ensure a holistic understanding of station area performance, the following profiles were developed for each selected station:

- ✓ **TOD Composite Score**: Aggregated from multiple TOD-related indicators, this score provides a benchmark to classify stations and identify gaps in performance relative to TOD principles.
- ✓ **Land-Use Diversity and Balance**: A key element of TOD is promoting mixed-use environments that reduce the need for long commutes and support active, vibrant urban life. Comparing diversity and balance across stations highlights areas that either support or hinder a walkable, multifunctional urban structure.

- ✓ **Urban Design Characteristics**: Physical form, public realm quality, pedestrian infrastructure, and connectivity are critical to the experiential and functional quality of TOD. These characteristics shape how people interact with space and whether they choose sustainable modes of transport.
- ✓ **Access to Services and Transit**: Equitable and efficient access to daily needs, amenities, and mobility options is essential for TOD success. This metric captures the practical usability of the station area for residents and commuters alike.
- ✓ **SWOT Analysis and Spatial Functionality**: By incorporating qualitative insights through SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis, the study integrates spatial realities, stakeholder perspectives, and development constraints. It also assesses the functional role each station plays in the broader urban system.
- ✓ Together, these comparative profiles offer a multidimensional understanding of what drives TOD success or failure. This approach not only aids in diagnosing current spatial challenges but also informs tailored recommendations for improving station-area development in line with TOD principles.

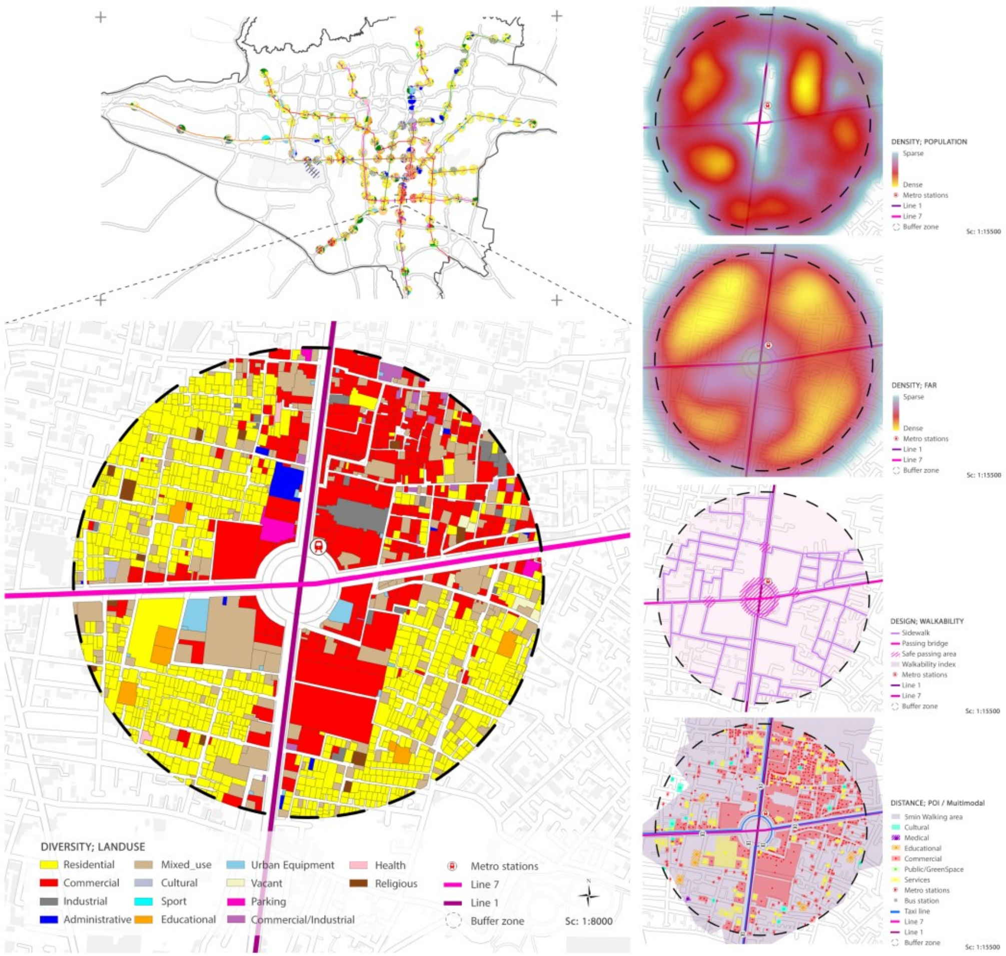
Name of station	Cluster	Rank	Tod score	Key indicators	Location	Special feature
MOHAMADIYE	**Successful and Balanced TOD Stations**	Highest	0.78	Very high walkability (0.99), strong access to services (1.00), excellent last-mile connectivity (0.80)	Historic city core, central Tehran	Multimodal hub with dense mixed uses and historical urban fabric
BOKHARAYI		Lowest	0.50	High population density (0.59), strong road connectivity (0.99), but low service availability (0.17)	South Tehran, mid-density residential zone	Mono-functional residential area with limited services
HOSSEINABAD	**Underperforming Stations**	Highest	0.16	Moderate land use diversity (0.62), low walkability (0.01), limited services (0.01)	East Tehran	Inadequate pedestrian design and limited local destinations
HEMAT		Lowest	0.06	Extremely low values in almost all indicators (walkability: 0.0018, service count: 0.0009)	Northern corridor	Isolated urban context with critical TOD deficits
KETAB	**Functionally Unbalanced**	Highest	0.30	High service area coverage (0.79), decent density (0.33) but weak walkability (0.12)	Western Tehran	High accessibility but low pedestrian orientation
SANA'AT		Lowest	0.18	Good multimodal connectivity (0.83), but very poor walkability (0.013) and services	Northwest Tehran	Transit connectivity without supportive land use or walkability
SABALAN	**Underdeveloped TOD Stations**	Highest	0.47	Very high population density (0.85), strong sidewalk coverage (0.91), moderate service access	Northeast Tehran	Dense area with partial TOD potentials but weak functional diversity
KASHANI		Lowest	0.31	High FAR (0.62), moderate diversity (Shannon: 0.64) but weak multimodal access (0.47)	Western corridor	High development intensity without transit integration

Table 9 TOD Performance Classification of Selected Tehran Metro Stations by author

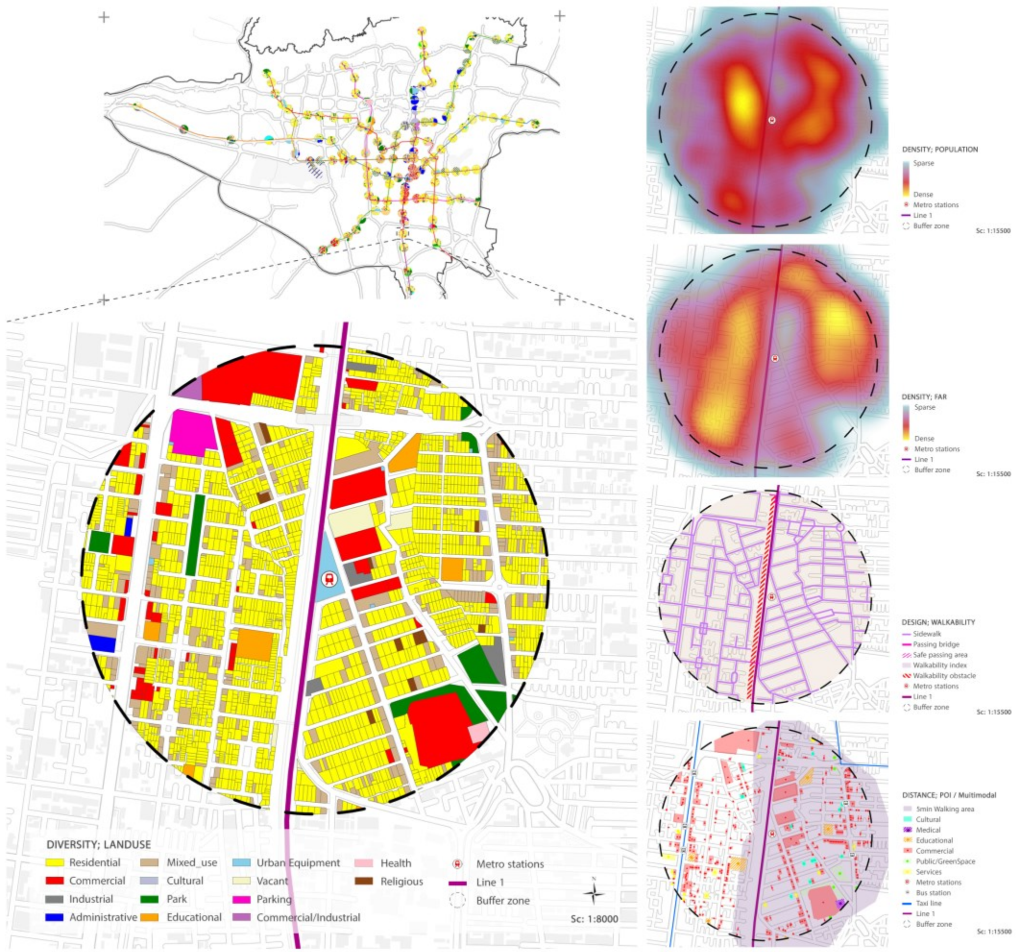
5.2 Intra-Cluster Comparison of Selected Stations

Before initiating a detailed comparison between individual stations within each cluster, it is important to contextualize the rationale behind intra-cluster analysis. While clustering helps group, stations based on shared spatial and functional characteristics, performance variations still exist within each typology. Intra-cluster comparison allows for a closer examination of these internal disparities, offering insights into how certain stations excel despite having similar contextual conditions, while others remain underperforming. This type of analysis not only highlights the strengths and weaknesses of individual cases but also reveals the underlying urban dynamics that drive TOD success or stagnation within similar spatial typologies.

MOHAMADIYE STATION: FIRST TOD RANK OF CLUSTER 1



BOKHARAYI STATION: LAST TOD RANK OF CLUSTER 1



S

High land-use diversity including commercial, educational, and medical functions within the 500-meter buffer

High building and population density, contributing to trip generation and urban activity

Strong integration between land use and transportation (connection to two metro lines and multimodal services)

Relatively well-structured urban design with active edges, fine-grain plots, and walkable street patterns

W

Lack of public open spaces or green areas near the station core

Over-concentration of commercial uses in some zones, reducing residential stability and increasing local congestion

Functional imbalance in certain segments (e.g., absence of healthcare or cultural land uses)

Inconsistent sidewalk quality and occasional

O

Potential for land-use upgrading through vertical mixed-use development (active ground floors with residential/office above)

Transforming underused plots into semi-public communal spaces

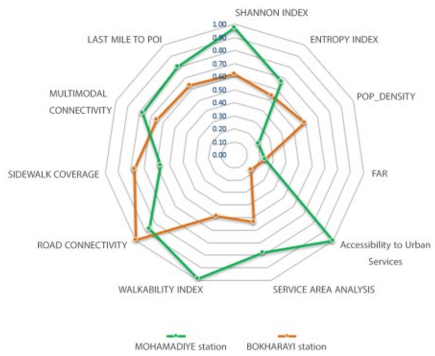
Reconnecting interrupted pedestrian paths to enhance walkability and urban permeability

T

Continued expansion of purely commercial uses may weaken residential livability and night-time activity

Lack of land-use regulation could lead to functional monotony or market-driven imbalance

Risk of gentrification and displacement of long-term residents due to rising land values



S

Presence of residential neighborhoods with potential for local trip generation

Semi-fine urban grain south of the station offers opportunities for public realm upgrades

Basic walkable access to metro station is already established

W

Extremely limited land-use diversity; dominated by residential function with lack of basic services (e.g., retail, education, healthcare)

No active public spaces or pedestrian-attracting uses

Poor street connectivity and inadequate pedestrian infrastructure

Lack of economic or service-based activity at the station's edges

O

Potential to introduce complementary land uses such as clinics, local retail, or community spaces in low-activity or vacant plots

Possibility of promoting denser residential developments with active ground floors (mixed-use models)

Activation of vacant lands for local-scale public space creation

T

Continued mono-functionality may deter private sector investment and reinforce transit underuse

Risk of increased car dependency due to lack of local amenities and walkable environments

Missed opportunities for TOD enhancement if no strategic intervention is applied in the near future

Figure 12 Intra-Cluster Comparison of high performing TOD stations by author

Cluster 1: Mohamadiyeh vs. Bokharaei

Although both Mohamadiyeh and Bokharaei stations are located within Cluster 1 - a relatively high-performing group in terms of overall TOD metrics - the two stations exhibit significant contrasts in terms of their actual Transit-Oriented Development (TOD) performance. This disparity highlights the importance of examining not only cluster-level classifications but also the local urban form, functionality, and land-use patterns that determine how TOD principles are manifested in practice.

Mohamadiyeh stands out as a leading example of successful TOD integration. It benefits from a highly diverse mix of land uses within its 500-meter catchment area, including commercial, educational, healthcare, and cultural functions. This diversity not only supports local trip generation but also contributes to a vibrant and active urban environment. Moreover, the station is characterized by a dense urban fabric, both in terms of population and built form, which reinforces its role as a dynamic hub of activity. Critically, Mohamadiyeh is served by two metro lines (Lines 1 and 7) and is well-connected to other modes of transport, such as buses and taxis, offering robust multimodal accessibility. The station area is further enhanced by a pedestrian-friendly urban design, featuring walkable streets, active frontages, and fine-grain urban blocks. These elements collectively enable a high level of land use–transport integration, positioning Mohamadiyeh as a model TOD node within the metropolitan system.

Despite these strengths, Mohamadiyeh also faces certain challenges that could hinder its long-term sustainability as a TOD hub. The lack of regulatory oversight on land-use mix poses risks of excessive commercialization and gentrification, which may erode residential stability and reduce socio-spatial equity. Furthermore, the continued expansion of purely commercial functions may compromise the quality of life for residents and disrupt the balance required for a resilient and inclusive TOD environment.

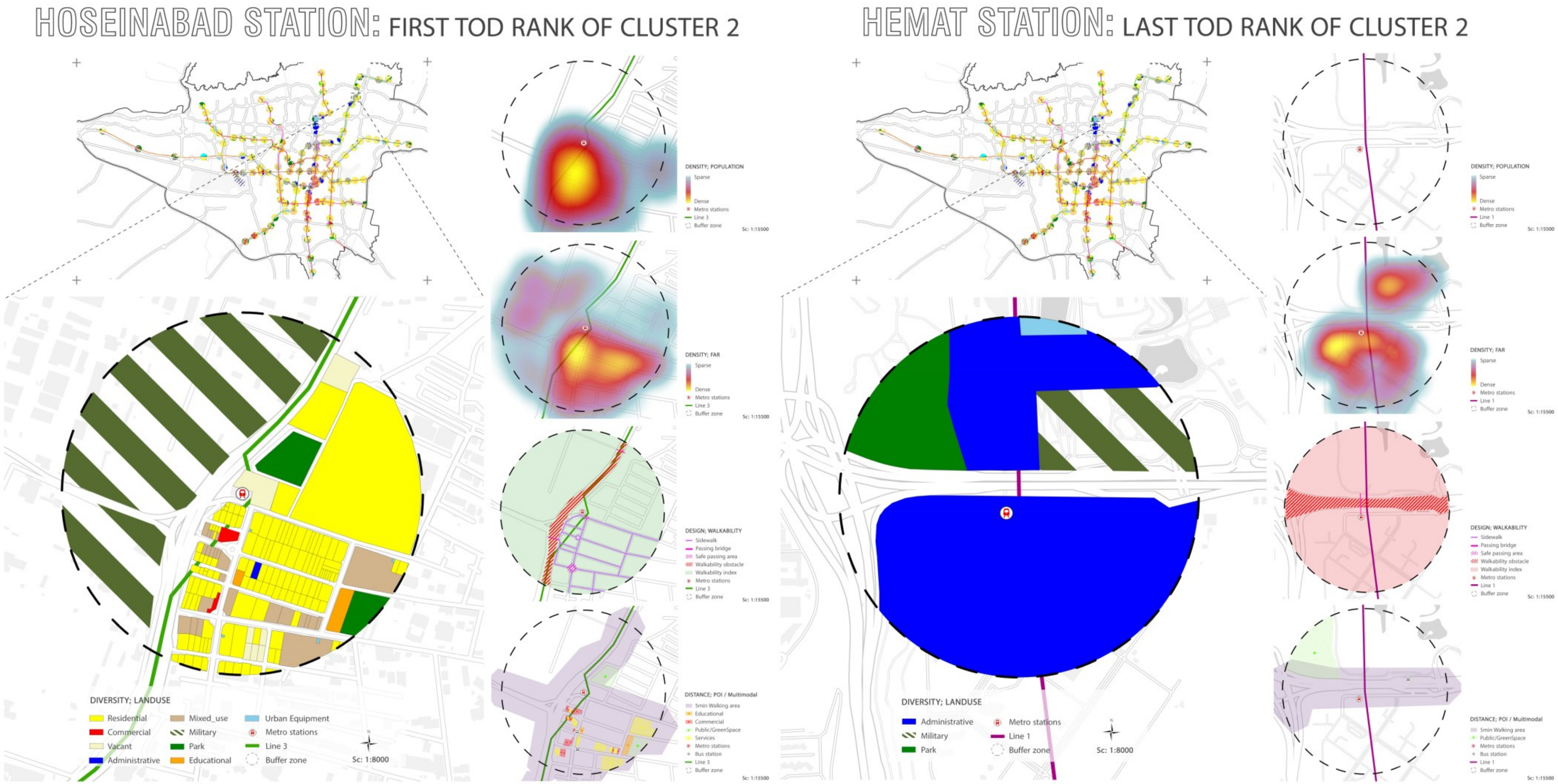
In contrast, Bokharaei represents a station with limited TOD performance, despite its inclusion in the same cluster. The primary land use in the area surrounding the station is residential, with minimal presence of complementary uses such as retail, educational institutions, or healthcare facilities. This mono-functionality limits the station’s capacity to generate diverse trip types or support vibrant public spaces. The physical infrastructure also reflects these limitations: pedestrian connectivity is weak, sidewalk conditions are inconsistent, and the public realm lacks active or attractive spaces. Although some semi-fine urban grain exists south of the station, the potential it offers remains untapped due to the absence of strategic development initiatives.

Nevertheless, Bokharaei does exhibit a few latent strengths. Its moderate residential density provides a foundation for TOD-compatible development, and the existing walkable access to the metro station - though basic - offers a platform for incremental improvements. If guided by targeted interventions such as the introduction of mixed-use developments, the enhancement of pedestrian infrastructure, and the activation of underused plots, Bokharaei could potentially evolve into a more TOD-aligned node.

In sum, this intra-cluster comparison reveals a crucial insight: classification within a high-performing TOD cluster does not automatically guarantee effective TOD outcomes at the station level. While Mohamadiyeh demonstrates how strategic integration of land use and transport can yield high performance, Bokharaei underscores the risks of relying solely on spatial proximity or basic density metrics. Achieving meaningful TOD outcomes requires deliberate and localized interventions that address the specific weaknesses and potentials of each station area. This finding reinforces the need for context-sensitive planning approaches that go beyond typological clustering and focus on on-the-ground functionality and spatial equity.

Figure 14 Aerial view of the Mohamadiyeh station buffer and surrounding entrance imagines, sourced from Google Maps

Figure 13Aerial view of the Bokharaei station buffer and surrounding entrance imagines, sourced from Google Maps



S

Presence of diverse land uses including cultural, educational, medical, commercial, and services

Balanced mix of public and private functions with accessible green/public spaces

High pedestrian connectivity with sidewalks, safe crossing points, and walkability elements

Dense urban fabric supports short-distance trip generation

Integration with bus lines enhances multimodal potential

O

Activation of cultural and educational parcels through community-oriented design

Improving vertical land use integration (residential + ground-floor activity)

Establishing small-scale plazas or shared-use spaces in green pockets

Using existing pedestrian infrastructure as a backbone for expanding TOD corridors

W

Some walkability obstacles remain in peripheral segments (e.g., wide intersections or narrow sidewalks)

Commercial and service uses are somewhat concentrated on a single edge

Lack of clearly designated TOD-oriented public plazas or gathering areas

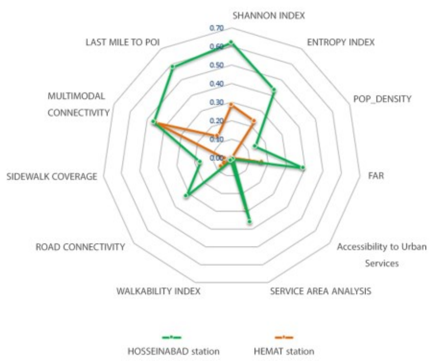
T

Pressure from traffic-dominant infrastructure may hinder long-term walkability

Fragmentation of functions due to non-unified design in private parcels

Land speculation could compromise land-use balance and TOD integrity

Possible saturation of service functions without functional zoning control



S

Located on a primary metro line (Line 2) with potential regional access

Some sidewalk segments and bridges present to support basic pedestrian flow

Presence of a few scattered educational and commercial plots within the buffer

O

Redevelopment of inactive plots or frontages into mixed-use TOD parcels

Targeted addition of local-scale services and commercial functions to activate street life

Implementation of pedestrian infrastructure upgrades (e.g., crossings, widened sidewalks)

Potential to define a TOD core by rezoning strategic parcels

W

Low land-use diversity: dominance of low-density residential and disconnected service parcels

Significant walkability obstacles including wide roads, lack of safe crossings, and sidewalk gaps

Poor spatial integration between the station and surrounding urban functions

Absence of public spaces or active commercial frontage near the station

Service area coverage and accessibility to POIs is severely limited

T

If current mono-functionality persists, the area may become increasingly car-dependent

Real estate underinvestment could limit transformation feasibility

Continued isolation from the surrounding urban fabric may deepen social and spatial segregation

Poor access to services could undermine transit ridership growth

Figure 15Intra-Cluster Comparison of underperforming TOD stations by author

Cluster 2: Hoseinabad vs. Hemat

The second cluster includes two highly contrasting cases: Hoseinabad, which demonstrates moderate alignment with TOD principles, and Hemat, which represents a critical failure point in terms of TOD performance. This comparison illustrates how both spatial integration and physical constraints can significantly influence the success or stagnation of TOD implementation.

Hoseinabad, the top-performing station in Cluster 2, presents a relatively balanced urban fabric. The station area includes a mix of residential, educational, commercial, and green spaces, creating an environment that supports diverse trip purposes. The pedestrian network around the station is moderately active, with sufficient sidewalk coverage and safe crossing infrastructure, contributing to walkability. In terms of urban form, Hoseinabad maintains mid-level population and floor area densities, which are sufficient to sustain localized TOD without overburdening infrastructure. Additionally, the area provides access to basic public services within a walkable distance and benefits from modest intermodal connectivity through nearby bus and taxi services.

However, Hoseinabad's performance is constrained by a lack of vertical land-use integration. Most buildings are single-purpose and lack the layering typical of effective TOD environments - such as active commercial ground floors combined with upper-floor residential units. Furthermore, the area suffers from underutilized or inactive public spaces and lacks a clear identity or branding as a TOD-oriented node. Without targeted interventions to enhance the spatial and functional coherence of the station area - such as infill development, micro public spaces, and place-making strategies - Hoseinabad risks falling short of its TOD potential. Zoning inconsistencies, sidewalk discontinuity, and functionally imbalanced subzones further limit its capacity to perform as a truly integrated TOD district.

In stark contrast, Hemat station - ranked lowest in Cluster 2 - exhibits a combination of spatial isolation and functional voids that severely undermine TOD performance. The area is predominantly composed of low-density, mono-functional residential land uses, with virtually no presence of supporting services such as retail, education, or health facilities. Pedestrian infrastructure is fragmented and of low quality, with major highways and arterial roads acting as physical barriers that disrupt continuity and urban cohesion. As a result, walkability is extremely poor, and service accessibility is minimal, forcing users to travel outside the station area to meet daily needs. The absence of active public spaces, ground-level services, or intermodal transfer facilities compounds the stations disconnect from its transit asset.

Hemat’s current condition reflects the cumulative impact of weak planning controls, inherited single-use zoning, and infrastructural fragmentation. Although some sidewalk segments and pedestrian bridges exist, they are insufficient to overcome the spatial isolation caused by surrounding expressways. The mismatch between the station's transport function and its adjacent land uses discourages investment, limits ridership, and reinforces car dependency. Without significant restructuring - including rezoning, redevelopment of vacant parcels for mixed use, and major upgrades to pedestrian and transit interfaces - Hemat will remain a critical gap in the city’s TOD network.

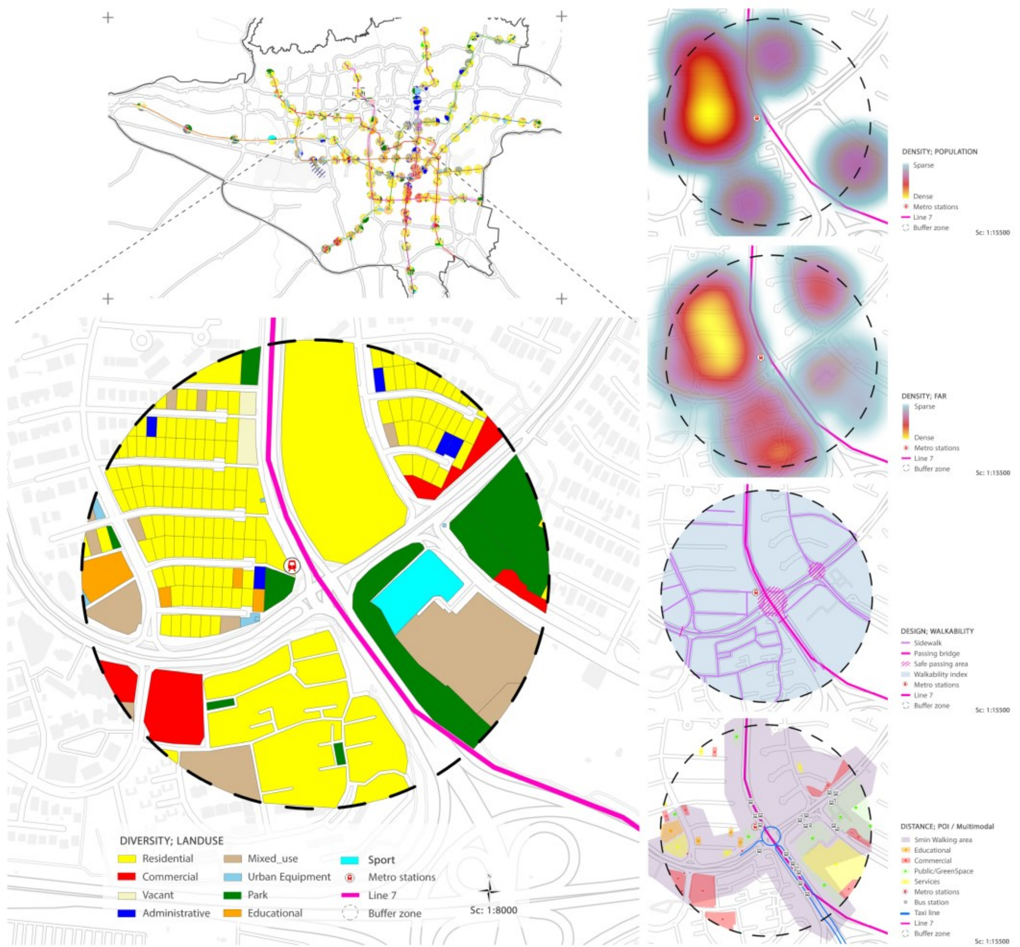
In summary, this comparison demonstrates that while Hoseinabad lacks refinement and vertical complexity, it still contains a foundational TOD structure that can be enhanced. In contrast, Hemat suffers from deep-rooted spatial and functional disconnections, positioning it as the most urgent candidate for comprehensive TOD intervention. This contrast within the same cluster underscores the importance of not just land-use metrics, but also physical integration, design quality, and regulatory alignment in shaping successful TOD outcomes.

Figure 17 Aerial view of the Hoseinabad station buffer and surrounding entrance imagines, sourced from Google Maps

Figure 16Aerial view of the Hemat station buffer and surrounding entrance images, sourced from Google Maps

KETAB STATION: FIRST TOD RANK OF CLUSTER 3

SANA'AT STATION: LAST TOD RANK OF CLUSTER 3



Ketab Station

S

- High diversity of land uses, including educational, commercial, green spaces, and cultural facilities
- Well-balanced spatial layout of land uses within the buffer, supporting functional integration
- Strong walkability supported by sufficient sidewalk coverage
- Proximity to multiple transit modes (bus and taxi), enabling multimodal access
- Active service zones along pedestrian corridors improve local accessibility

O

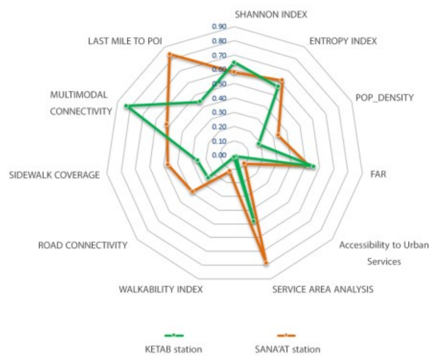
- Potential to enhance the urban interface of educational and cultural plots with ground-floor activation
- Underused parcels near the metro entrance can be developed into mixed-use infill projects
- Capacity to brand the station as a cultural–educational TOD node in the western corridor

W

- Lack of clear land use zoning may result in functional overlaps and conflicts
- Some commercial parcels are disconnected from the station's access points
- Absence of TOD-focused public gathering spaces or urban plazas
- Eastern edge lacks strong pedestrian connection to surrounding neighborhoods

T

- Risk of land use fragmentation due to unregulated commercial expansion
- Uneven pedestrian environment may limit the effectiveness of TOD policies
- Market-driven development could overlook TOD principles without planning control
- Increasing land prices may lead to displacement of



Sana'at Station

S

- Existing industrial/office land uses with potential for functional transformation
- Partial sidewalk presence along some internal streets
- Located on Metro Line 7, with potential for integration into the broader TOD network

O

- Opportunity to convert industrial plots into TOD-compatible mixed-use developments
- Integration of local-scale retail and services to reduce dependency on motorized travel
- Potential for creating urban green space or a transit plaza on underutilized land
- Rebranding San'at as a future employment hub within a TOD framework

W

- Extremely low land-use diversity, with dominance of mono-functional industrial blocks
- Lack of services, commercial activity, and community-based land uses
- Weak pedestrian infrastructure and low network permeability
- Absence of active frontages or vibrant urban edges around the station

T

- Industrial zoning inertia may inhibit transformation into a mixed-use node
- Limited investor interest without planning incentives or infrastructure upgrades
- Aging infrastructure and building stock may limit redevelopment feasibility
- Low residential presence weakens the potential for trip generation and street activation

Figure 18 Intra-Cluster Comparison of functionally unbalanced nodes stations by author

Cluster 3: Ketab vs. San’at

The third cluster juxtaposes two sharply contrasting station environments: Ketab, which exhibits many of the physical and functional qualities of a successful TOD node, and San’at, which remains hindered by industrial land use inertia and structural barriers to transformation. This contrast underscores the importance of not only land-use composition but also spatial integration, zoning coherence, and supportive planning frameworks.

Ketab station, ranked highest in Cluster 3, demonstrates strong alignment with key TOD principles. Its immediate catchment area features a highly diverse mix of land uses, including educational, cultural, commercial, and green space functions. The spatial distribution of these uses is relatively balanced, creating opportunities for integrated activity patterns and localized trip generation. The station benefits from a pedestrian-friendly urban form, with adequate sidewalk coverage and walkable access to adjacent amenities. Additionally, its proximity to multimodal services - including bus and taxi routes - enhances connectivity and supports a seamless transition between different forms of transit. The presence of active ground-floor services along key corridors further strengthens the walkability and service accessibility of the area.

Despite these advantages, Ketab remains situated within a mid-performing cluster due to persistent planning and spatial integration issues. Zoning inconsistencies and the absence of coordinated land-use regulation have led to fragmented development patterns and isolated commercial nodes. In particular, some service functions are disconnected from the station’s main pedestrian axis, and key transition zones - especially along the station’s eastern edge - suffer from weak pedestrian permeability. Moreover, the lack of designated public gathering spaces or TOD-branded interventions prevents the station from achieving its full place-making potential. Without targeted planning policies, such as infill development strategies, pedestrian connectivity enhancements, and public realm activation, Ketab’s TOD success may remain constrained by systemic urban design gaps.

In contrast, San’at station presents a more structurally challenged environment, characterized by mono-functional industrial land use and extremely low residential or commercial presence. The station is surrounded by aging industrial buildings and office complexes, with minimal services or amenities that could support daily life or stimulate foot traffic. The pedestrian infrastructure is underdeveloped, with weak connectivity and poor-quality public spaces. The absence of active frontages, service-based functions, or community-oriented facilities results in a sterile and inactive urban edge. As a result, both trip generation and public realm vitality remain low, undermining the potential for TOD-related transformation.

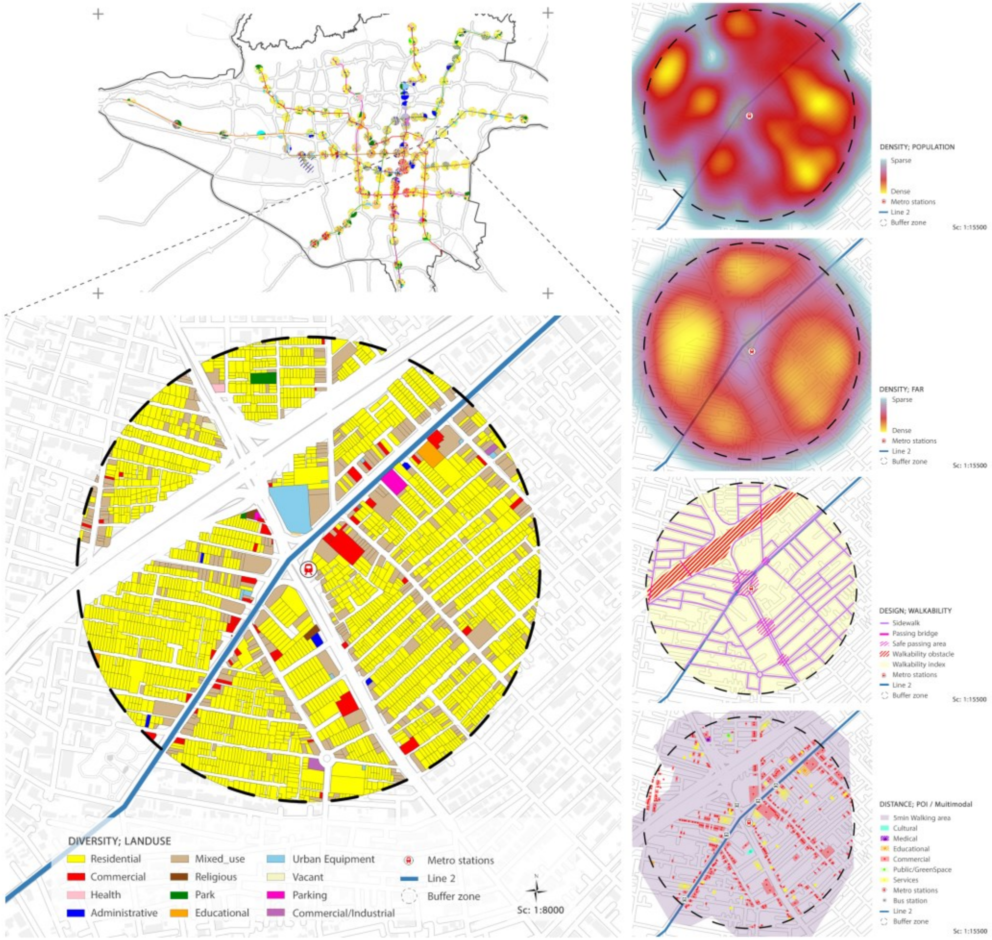
San’at’s current condition is largely a result of historical zoning and functional rigidity. However, its location on Metro Line 7 offers a strategic opportunity for integration into the broader TOD network, should transformation be pursued through policy support. Vacant or underutilized parcels within the station’s influence zone could be targeted for redevelopment into mixed-use or employment-based TOD typologies. Integrating local-scale retail, introducing urban green space, and improving pedestrian networks could begin to shift the area’s functional identity. Yet, such interventions require strong incentives and infrastructure upgrades to overcome industrial inertia and attract investment.

In conclusion, this intra-cluster comparison highlights a crucial lesson: even when a station like Ketab demonstrates a strong land-use mix and walkability, its TOD effectiveness can be weakened by poor spatial cohesion and fragmented governance. Meanwhile, San’at illustrates the deep-rooted challenges faced by industrial zones, where transformation requires not only design interventions but also structural policy shifts and economic incentives. This comparison reaffirms that successful TOD is not simply a function of density or diversity, but of holistic alignment between land use, design, access, and policy support.

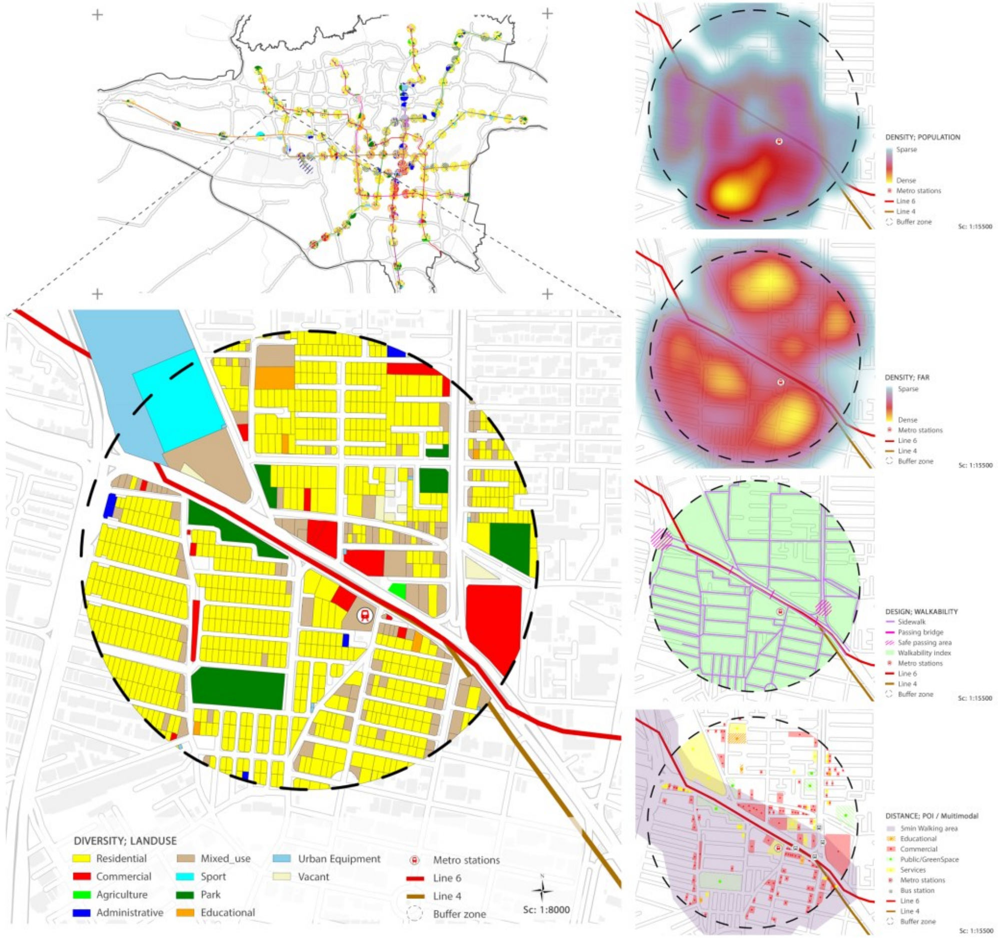
Figure 20 Aerial view of the Ketab station buffer and surrounding entrance imagines, sourced from Google Maps

Figure 19 Aerial view of the San'at station buffer and surrounding entrance imagines, sourced from Google Maps

SABALAN STATION: FIRST TOD RANK OF CLUSTER 4



KASHANI STATION: LAST TOD RANK OF CLUSTER 4



S

High diversity of land uses, including educational, commercial, green spaces, and cultural facilities

Well-balanced spatial layout of land uses within the buffer, supporting functional integration

Strong walkability supported by sufficient sidewalk coverage

Proximity to multiple transit modes (bus and taxi), enabling multimodal access

Active service zones along pedestrian corridors improve local accessibility

O

Potential to enhance the urban interface of educational and cultural plots with ground-floor activation

Underused parcels near the metro entrance can be developed into mixed-use infill projects

Capacity to brand the station as a cultural–educational TOD node in the western corridor

W

Lack of clear land use zoning may result in functional overlaps and conflicts

Some commercial parcels are disconnected from the station's access points

Absence of TOD-focused public gathering spaces or urban plazas

Eastern edge lacks strong pedestrian connection to surrounding neighborhoods

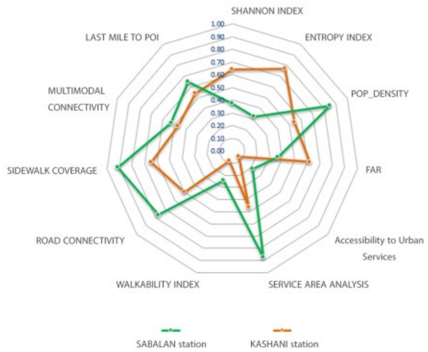
T

Risk of land use fragmentation due to unregulated commercial expansion

Uneven pedestrian environment may limit the effectiveness of TOD policies

Market-driven development could overlook TOD principles without planning control

Increasing land prices may lead to displacement of



S

Existing industrial/office land uses with potential for functional transformation

Partial sidewalk presence along some internal streets

Located on Metro Line 7, with potential for integration into the broader TOD network

O

Opportunity to convert industrial plots into TOD-compatible mixed-use developments

Integration of local-scale retail and services to reduce dependency on motorized travel

Potential for creating urban green space or a transit plaza on underutilized land

Rebranding San'at as a future employment hub within a TOD framework

W

Extremely low land-use diversity, with dominance of mono-functional industrial blocks

Lack of services, commercial activity, and community-based land uses

Weak pedestrian infrastructure and low network permeability

Absence of active frontages or vibrant urban edges around the station

T

Industrial zoning inertia may inhibit transformation into a mixed-use node

Limited investor interest without planning incentives or infrastructure upgrades

Aging infrastructure and building stock may limit redevelopment feasibility

Low residential presence weakens the potential for trip generation and street activation

Figure 21 Intra-Cluster Comparison of underdeveloped TOD stations by author

Cluster 4: Sabalan vs. Kashani

Cluster 4 presents a compelling contrast between Sabalan - a station with emerging TOD strengths - and Kashani, a location significantly constrained by spatial and social disconnection. This comparison illustrates how both fine-grain urban design and integrated land-use planning are necessary to advance TOD performance, even within lower-performing typological clusters.

Sabalan station, ranked highest in Cluster 4, benefits from a relatively rich and diverse land-use pattern. The area around the station includes cultural, medical, educational, and commercial uses, creating a varied urban environment conducive to TOD objectives. The urban fabric is dense and walkable, supported by a connected street grid, safe crossing points, and established pedestrian infrastructure. Additionally, Sabalan offers access to green and semi-public open spaces, which enhance its livability and spatial quality. Integration with bus lines strengthens its multimodal functionality and supports non-car mobility. Despite these advantages, Sabalan's TOD performance is moderated by several design and organizational issues. Services and commercial activities are disproportionately concentrated along a single edge, leading to functional imbalance within the station buffer. Furthermore, the absence of clearly defined public plazas or gathering spaces limits opportunities for place-making and community engagement.

To realize its full TOD potential, Sabalan would benefit from strategic upgrades. These could include activating underused cultural and educational parcels, introducing small-scale plazas or shared spaces, and strengthening vertical land-use integration by encouraging mixed-use buildings with active ground floors. Such improvements would reinforce the station's role as a local urban hub and create a more legible, inclusive TOD environment.

In contrast, Kashani station - the lowest-ranked in Cluster 4 - suffers from a combination of physical fragmentation, poor land-use integration, and weak pedestrian infrastructure. The area surrounding the station is dominated by low-density residential uses, with few public services and minimal commercial activity. Walkability is severely compromised by wide road crossings, disconnected sidewalks, and an overall lack of pedestrian continuity. Services are not only sparse but also spatially disconnected from the station core, further reducing functional accessibility. Moreover, there are no active frontages, plazas, or inviting public spaces in the immediate vicinity, leading to a low level of public realm activation.

Kashani’s TOD stagnation is further reinforced by its social and spatial isolation. The station lacks a coherent functional identity and remains cut off from the surrounding urban fabric. In the absence of strategic planning or investment, there is a risk that the area could become increasingly car-dependent and further detached from the broader transit network. Nonetheless, opportunities exist to reposition the station within a TOD framework. These include repurposing vacant plots into mixed-use developments, enhancing pedestrian infrastructure, and defining a TOD core through targeted rezoning. However, without addressing the foundational gaps in land use and connectivity, TOD transformation at Kashani is unlikely to occur organically.

This comparison makes clear that while Sabalan shows promise for TOD improvement through incremental urban design and land-use redistribution, Kashani represents a more critical case. Its limitations stem not just from land-use composition but from a deeper disconnect between transit infrastructure and the surrounding urban context. Addressing such disconnection requires a multifaceted strategy involving spatial reconfiguration, service expansion, and social reintegration.

Figure 23 Aerial view of the Sabalan station buffer and surrounding entrance imagines, sourced from Google Maps

Figure 22 Aerial view of the Kashani station buffer and surrounding entrance imagines, sourced from Google Maps

5.3 Evaluation of Upgrade Potential in High-Ranked Stations

Ketab, and Sabalan - demonstrate clear spatial and functional strengths that distinguish them within their respective typologies. However, despite their favorable positions, none have yet reached their full TOD potential. Their stagnation at mid-tier performance levels reflects limitations not in foundational capacity, but in the absence of coordinated policies and targeted spatial interventions. Key findings include:

Station	Upgrade Potential
Mohamadiyeh	Lacks open public space; needs vertical mixed-use intensification
Hoseinabad	Needs TOD branding, active public realm, and better zoning articulation
Ketab	Requires clear zoning, TOD plaza, and edge activation
Sabalan	Opportunities in balancing services and creating community hubs

Mohamadiyeh, for example, offers a robust foundation for TOD, including dense mixed uses, multimodal access, and active street life. Nevertheless, the lack of structured public space and vertical land-use layering limits the station's ability to evolve into a comprehensive urban hub. Its growth has been largely organic and market-driven, with insufficient regulatory guidance to direct spatial quality. As a result, while activity levels are high, the station remains vulnerable to gentrification and land-use imbalance. With strategic interventions - such as regulating ground-floor activation, designating civic space, and promoting vertical mixed-use typologies - Mohamadiyeh could transition into a flagship TOD exemplar.

Hoseinabad remains under-leveraged due to its lack of identity and weak public realm design. While the urban form supports pedestrian access and service diversity, the absence of clear TOD branding, fragmented sidewalk conditions, and underutilized public land parcels prevent it from generating the kind of place-based character critical for TOD success. If supported by zoning reforms, land consolidation efforts, and community-scale design interventions (e.g., TOD plazas, wayfinding, and branding), the station could move from a functionally adequate zone to an active neighborhood TOD hub.

Ketab exhibits several TOD-aligned features, including land-use diversity and transit proximity. Yet, it has not progressed due to regulatory fragmentation and the lack of cohesive planning. Conflicts between different land uses, inconsistent pedestrian experience, and missing centrality in the station core contribute to spatial incoherence. These gaps could be addressed through rezoning efforts, pedestrian realm upgrades, and the introduction of civic space to create a recognizable and legible TOD identity.

Sabalan, while functionally vibrant, is constrained by an imbalanced distribution of services and absence of formal gathering spaces. The current development pattern is uneven, with peripheral walkability issues and service clustering on a single edge. If future interventions can introduce small-scale plazas, decentralize services, and enhance sidewalk continuity, Sabalan could emerge as a highly livable and community-centered TOD node.

In all cases, the reason these stations - despite being ranked highest in their clusters - have not evolved further lies in a lack of integrated TOD planning and policy articulation. Their future success depends not on large-scale redevelopment but on targeted, fine-grain design improvements and policy alignment, which would unlock their latent potential and elevate their TOD performance.

5.4 Diagnosis of Low-Ranked Stations: Causes of Stagnation

The lowest-ranked stations - **Bokharaei, Hemat, San'at, and Kashani** - share a set of persistent structural challenges that explain their continued underperformance. These include mono-functional land use (residential or industrial), poor service accessibility, limited pedestrian infrastructure, and an overall lack of spatial integration with their respective transit assets.

Common Issues
Dominance of mono-functional residential or industrial uses
Lack of services and commercial activation
Poor walkability and weak network permeability
Absence of public or civic spaces

However, their continued stagnation is not inevitable - it results from a combination of passive neglect, rigid zoning regimes, and missed planning opportunities. For instance, Bokharaei, despite being located in a central area, remains low-performing because of its extremely low land-use diversity and passive public realm. Without incentives for mixed-use infill or activation of public space, the area has remained inert. Yet, if even modest investments were made in pedestrian design and service diversification, Bokharaei could leverage its centrality to shift toward moderate TOD performance.

Hemat, conversely, is physically severed from the urban grid by highways and suffers from complete service absence and pedestrian discontinuity. Its poor connectivity limits both functional integration and social vitality. If these barriers are not addressed, Hemat risks further marginalization and increased car dependency. However, strategic interventions - such

as pedestrian bridges, service clustering, and targeted rezoning - could reconnect the station to the broader urban system.
San’at suffers from functional rigidity due to its industrial legacy. Land speculation, outdated zoning, and aging infrastructure have created an environment unsuitable for TOD. In the absence of planning incentives and infrastructure upgrades, the area is likely to continue declining. Yet, if transformation were supported through phased redevelopment (e.g., converting industrial plots to mixed-use employment zones), San’at could become a productive urban node.
Finally, Kashani exemplifies a fragmented, under-served residential area with low walkability and limited accessibility. Its current state is the result of underinvestment and planning vacuum. If no action is taken, this fragmentation could deepen, reducing land values and transit usage further. On the other hand, a strategy of land readjustment, streetscape improvements, and creation of a TOD core through anchor projects could reverse its stagnation trajectory.
In essence, the continued weakness of these low-ranked stations is not predetermined. They remain locked in place due to institutional inertia, uncoordinated planning, and limited investment. However, if strategic, place-based policies and design frameworks are applied, they can shift toward TOD alignment. Conversely, without intervention, these areas may not only remain stagnant but deteriorate further, increasing spatial inequality and transit inefficiency.

5.5 HEMAT Station – Deep Dive and Strategic Land-Use Proposal

Hemat Metro Station represents a critical yet underutilized node within Tehran’s transit network. Despite its infrastructural capacity, the station is spatially isolated, surrounded by mono-functional institutional uses, and suffers from weak pedestrian and land-use integration. These limitations are not solely physical; they are symptomatic of policy misalignments, rigid zoning, and fragmented governance, which collectively hinder the application of Transit-Oriented Development (TOD) principles.
This section presents a policy-oriented TOD redevelopment strategy tailored to Hemat Station. It builds on Iranian urban development policies while integrating global land-use strategies for TOD as recommended by the ITDP, World Bank TOD Toolkit, and UN-Habitat. The objective is to demonstrate how Iran’s existing planning framework - including the National TOD Design Guide, SCUPA land-use regulations, and Tehran’s Comprehensive

Plan - can be leveraged to retrofit Hemat into a more integrated, accessible, and vibrant urban node.

5.5.1 Strategic Policy Objectives

This framework responds to four interrelated TOD challenges identified in the thesis:

- Misalignment between transit infrastructure and surrounding land use
- Physical and perceptual disconnect from the pedestrian network
- Regulatory and institutional rigidity in land-use planning
- Lack of locally grounded, replicable TOD models for non-residential metro stations

The corresponding strategic objectives are:

1. **Enable adaptive land-use integration** through policy flexibility.
2. **Improve pedestrian access and station legibility** using national design guidelines.
3. **Activate underutilized institutional land** via controlled public programming.
4. **Introduce mixed-use and civic services** to expand trip purposes and improve safety.
5. **Institutionalize inter-agency collaboration** as a governance innovation.

5.5.2 Policy-Aligned Proposals for Hemat Station

Building on the spatial analysis and typological assessment presented earlier, this section outlines a series of design and planning interventions for Hemat Station, structured under the Place–Function–Design (PFD) framework. Each proposal is directly informed by the core challenges identified in the case study - such as institutional land inaccessibility, lack of land-use diversity, and pedestrian disconnection - and is evaluated for its alignment with the thesis objectives, hypotheses, and research questions. In addition, all proposed strategies are grounded in relevant Iranian urban policy frameworks, including the National TOD Guideline (2020), the Tehran Comprehensive Plan (2007), and tactical design approaches endorsed by SCUPA. The expected impacts aim to enhance TOD performance at both the spatial and governance levels, offering replicable models for low-performing transit nodes elsewhere in Tehran.

1. Forecourt Plaza Redesign

Problem Addressed: Spatial ambiguity, inactive ground floor edges, and lack of urban legibility.

Proposal: Transform the existing forecourt into an urban gateway with shaded seating, defined edges, and ground-floor activation (cafés, kiosks).
Related Objective: Enhancing spatial quality and identity around station areas (Objective 1).
Hypothesis Tested: H3 – Weak walkability and user experience hinder TOD performance.
Policy Basis: SCUPA Node Design Guidelines; Tehran Comprehensive Plan (2007).
Expected Impact: Increases station legibility, improves arrival experience, and fosters civic identity.

2. East–West Spatial Reconnection

Problem Addressed: Physical barriers from institutional walls hinder pedestrian movement.
Proposal: Introduce permeable paths, urban art, and lighting to connect urban blocks.
Related Objective: Improve pedestrian connectivity and public realm integration (Objective 3).
Research Question Addressed: How can non-zoning tools improve walkability around TOD nodes?
Policy Basis: National TOD Guide (2020), Urban Regeneration Strategy.
Expected Impact: Restores street legibility, strengthens local circulation networks.

3. Green Mobility Belt

Problem Addressed: Edge condition dominated by highways with poor environmental quality.
Proposal: Create a green linear corridor with shaded walking/cycling paths and landscape buffers.
Related Objective: Enhance environmental comfort and last-mile accessibility (Objective 3).
Hypothesis Tested: H3 – Poor accessibility and fragmentation limit TOD success.
Policy Basis: Green Artery Program; TOD Public Space Guidelines.
Expected Impact: Buffers negative highway impact, provides active frontage, and promotes non-motorized travel.

4. Mixed-Use Southern Buffer

Problem Addressed: Low-density institutional use fails to support transit-oriented life.
Proposal: Convert administrative land to mixed-use (residential, retail, civic) with mid-rise blocks.
Related Objective: Enable adaptive land use integration and densification (Objective 1).
Hypothesis Tested: H1 – Low functional diversity undermines TOD.
Policy Basis: National TOD Design Guide (Chapter 5); Tehran Detailed Plan.
Expected Impact: Introduces residential base, ensures functional mix, and supports trip generation.

5. Distributed Micro-Service Nodes

Problem Addressed: Lack of street-level activity and service diversity.
Proposal: Install micro-infrastructure (co-working pods, kiosks, book cafés) along pedestrian axes.
Related Objective: Expand public service accessibility and informal economy (Objective 2).
Research Question Addressed: How can flexible urban forms support TOD in restricted contexts?
Policy Basis: Tactical Urbanism Framework (SCUPA); TOD Mixed-Use Guidelines.
Expected Impact: Enhances ground-level activation, fosters informal social interaction.

6. Short-Term Housing Overlay

Problem Addressed: No permanent population near station; dormitory and housing demand unmet.
Proposal: Provide modular housing for public employees/students on state land.
Related Objective: Encourage residential presence in TOD zones (Objective 1).
Hypothesis Tested: H1 – Residential scarcity reduces round-the-clock activity.
Policy Basis: Tehran Affordable Housing Initiative; TOD Residential Incentive Policies.
Expected Impact: Supports continuous land use, reduces car dependency, and increases equity.

7. Ground-Floor Activation of Institutional Buildings

Problem Addressed: Blank façades limit visual engagement and passive safety.

Proposal: Retrofit façades with small commercial units (e.g., bakeries, print shops, lockers).

Related Objective: Foster urban vibrancy through tactical retrofitting (Objective 1).

Policy Basis: TOD Active Frontage Regulation (SCUPA); Tehran Retrofit Incentives.

Expected Impact: Boosts street life, enhances passive surveillance, and supports diverse use.

8. Wayfinding and Urban Furniture Enhancement

Problem Addressed: Poor navigability and lack of pedestrian amenities.

Proposal: Add tactile paths, signage, lighting, benches, and fountains.

Related Objective: Improve walkability and user orientation in station areas (Objective 3).

Hypothesis Tested: H3 – Design interventions improve spatial experience and equity.

Policy Basis: Universal Access Plan (Tehran); TOD Design Guide Article 2.4.

Expected Impact: Inclusive public realm, especially for elderly, disabled, and children.

9. Inclusive Pedestrian Bridge

Problem Addressed: Physical disconnection due to highway infrastructure.

Proposal: Build an accessible bridge or underpass with ramps, shading, and night-time safety features.

Related Objective: Enable safe pedestrian crossing and spatial reconnection (Objective 3).

Policy Basis: Tehran Universal Access Plan; TOD Guide 2.4.

Expected Impact: Reduces car reliance, improves safety, and restores human-scale connectivity.

5.5.3 Governance and Implementation Tools

Beyond spatial design, successful TOD retrofitting requires governance innovation and financial sustainability:

A. Pilot TOD Governance Platform

Proposal: Establish a Hemat Station TOD Committee including the Tehran Metro Co., District Municipality, and institutional landowners.

Policy Basis: National Urban Regeneration Strategy (Cross-Sector Collaboration Clause).

Function: Oversee implementation, coordinate interventions, and manage public-private negotiations.

B. Value Capture via Semi-Public Land Use

Proposal: Allow limited revenue-generating uses on institutional land (e.g., food stands, fairs) in exchange for reinvestment in public realm improvements.

Policy Basis: Iran's Urban Investment Regulation; Value Capture Pilots in Ekbatan.

Impact: Creates fiscal incentives for institutional stakeholders to support TOD improvements.

Policy Goal	Proposal	Relevant Policy	Expected Impact
Mixed-use redevelopment in southern buffer	Functional conversion + vertical integration	National TOD Design Guide, article 5 + detailed plan of region 2	Introduces residential density and activates TOD potential
Increase public realm quality	Station plaza	SCUPA node design regulations	Enhances legibility and multimodal access
Activate underused institutional land	MoU for semi-public use	TOD Guide 4.3; SCUPA	Low-risk land-use diversification
Reconnect fragmented fabrics	Linear green corridor	National Urban Regeneration Strategy; Green Artery Program	Environmental comfort and connectivity
Expand destination variety	Civic-service micro-hub	Tehran's special location plan; TOD Mixed-Use Guidelines	Trip generation and safety through passive surveillance
Foster community engagement	Temporary cultural events	SCUPA Tactical Urbanism Framework	Low-cost, participatory urbanism
Enable inclusive pedestrian access	Pedestrian bridge + upgraded crossings	TOD Guide 2.4; Tehran Universal Access Plan	Reduces barriers and improves safety
Improve last-mile integration	Feeder shuttle service	TOD Guide 3.2; Tehran Bus Co. Feeder Plan	Higher accessibility and system efficiency
Enhance arrival experience and identity	Access node plazas	Node-based Urban Design Model	Improves wayfinding and spatial quality

Table 10 Policy-Proposal Matrix by author

The Hemat Station TOD strategy is not a design vision alone - it is a policy implementation framework. By mobilizing existing Iranian planning instruments, from SCUPA zoning flexibilities to Tehran's local regeneration strategies, this proposal offers a replicable, low-cost, and politically feasible roadmap for station-area transformation.
Rather than aiming for wholesale redevelopment, this approach promotes incremental change, inter-agency cooperation, and contextual adaptation. It demonstrates that even in constrained, institutional-dominated environments, a combination of policy innovation, tactical urbanism, and governance alignment can re-anchor the station into the urban fabric - making it not only a transit node, but a civic landmark.

5.6 Synthesis and Forward Path

The comparative case study of eight stations across four TOD clusters highlights a central insight: TOD success is not determined solely by the presence of transit infrastructure. Rather, it hinges on the quality and integration of land use, pedestrian design, service accessibility, and governance alignment. Merely providing a metro station is insufficient. The surrounding urban environment must be structured to support transit usage, local vitality, and spatial equity.

Several key strategic lessons emerge:

- **Strong stations**, such as Mohamadiyeh and Ketab, are limited not by potential but by lack of coordinated planning. Tactical interventions in public space design, vertical integration, and zoning enforcement can elevate them to model TOD nodes.
- **Weak stations**, such as Hemat and San'at, require more fundamental land-use restructuring. Their stagnation is not merely a result of poor connectivity but of structural isolation, functional voids, and regulatory rigidity.
- **Hemat**, in particular, represents a critical testbed for TOD transformation in Tehran. Its extreme underperformance illustrates the consequences of car-dominated planning and mono-functional zoning. At the same time, it offers a unique opportunity: precisely because of its poor condition, it provides a blank canvas for demonstrating how TOD principles can be applied in low-performance urban areas.

Looking forward, these findings establish the conceptual foundation for Chapter 6, which presents a detailed TOD design proposal for Hemat station. This proposal operationalizes the strategic recommendations discussed here and offers a replicable framework for TOD retrofitting in similar contexts across the city.

Chapter 6

Land Use Design Strategies for Low-Performing TOD Metro Stations (HEMAT)

6.1 From Infrastructure to Spatial Function: A Shift in Perspective

Conventional approaches to Transit-Oriented Development (TOD) often prioritize the physical proximity of built environments to transit infrastructure, relying heavily on spatial metrics such as density, diversity, and distance. While these indicators are critical for assessing urban efficiency and compactness, they provide only a partial understanding of how spaces actually operate or contribute to a successful TOD environment. Particularly in cities like Tehran, where complex land ownership, disconnected land uses, and institutional fragmentation frequently undermine TOD goals, a purely infrastructural or metric-based approach proves insufficient.

This chapter adopts a new conceptual orientation - one that shifts the focus from static infrastructure to the dynamic interplay of place, function, and design. The Place–Function–Design (PFD) framework proposed here redefines the core of TOD success: not merely the existence of transit facilities, but the strategic programming and integration of surrounding land uses that enable spatial functionality, encourage activity, and ensure long-term adaptability. This approach recognizes that effective TOD must be measured not only by what is built, but by how land is used, for what purposes, and how spatial configurations support these functions in practice.

The rationale for using the PFD model in this thesis lies in its ability to overcome the limitations of form-based or infrastructure-centered planning. It offers a three-tiered lens:

- **Place** refers to the spatial context and character of a location - its visibility, structure, accessibility, and social relevance.
- **Function** addresses the actual and intended uses of that place - residential, commercial, institutional, recreational - and how these uses relate to the surrounding urban system.
- **Design** concerns the physical articulation of space in terms of layout, form, density, and connectivity that supports and amplifies the functional goals of each place.

This model is especially well-suited to Tehran's TOD challenges. For instance, around HEMAT Station, the presence of transport infrastructure has not led to functional integration or spatial coherence. Large institutional land holdings remain fenced and inactive, land use is fragmented and monofunctional, and public life is sparse. Applying the PFD approach allows for a reinterpretation of these conditions - not as static constraints, but as latent opportunities. A fenced plot, for example, is understood not simply as inaccessible land, but as a place with potential civic function, contingent on institutional cooperation and appropriate design interventions. Similarly, underutilized office buildings are reimagined as candidates for functional reprogramming - introducing commercial activity on the ground floor or combining short-term residential units with office use to generate 24-hour vitality. The benefits of the PFD model for this thesis are both analytical and operational. Analytically, it allows for the mapping of land use not as a fixed zoning category, but as a dynamic spectrum of functional capacities. Operationally, it links spatial problems to targeted, scalable design solutions. This shift makes the design process not only more grounded in existing urban realities, but also more policy-relevant - offering implementable strategies that align with Tehran’s evolving regulatory environment and urban development priorities.

In sum, the Place–Function–Design framework serves as a powerful intermediary between TOD theory and spatial action. It enables the thesis to respond more directly to the core research questions - namely, how to reprogram land around underperforming transit stations, how to overcome institutional and spatial rigidities, and how to structure land uses that support density, diversity, and access. By moving beyond infrastructure toward function-driven, place-based interventions, this chapter offers a grounded, context-aware, and policy-compatible approach to TOD improvement in Tehran.

6.2 Land Use Strategies in the TOD Context (Iran-Adapted)

Effective Transit-Oriented Development (TOD) requires more than the provision of transit infrastructure; it demands a deliberate restructuring of surrounding land uses to support dense, vibrant, and connected urban life. In the Iranian context - and specifically in Tehran - this task is particularly complex due to the presence of vast mono-functional zones, institutional land control, and a fragmented governance structure. As noted in the Tehran Comprehensive Plan (2007) and Tehran TOD Pilot Studies (Tehran Municipality, 2020), several land-use strategies have been identified to better align urban development with TOD principles in a manner that responds to local governance and spatial realities.

One foundational strategy is the promotion of mixed-use development, both vertically (within buildings) and horizontally (across blocks). This reflects global TOD literature (Calthorpe, 1993; Dittmar & Ohland, 2004), which emphasizes that land-use diversity near stations encourages 24-hour activity, reduces car dependency, and improves safety through passive surveillance. In Tehran’s case, particularly around stations like HEMAT, single-use zoning dominated by institutional or administrative functions has produced sterile, underutilized spaces. Encouraging a fine-grained mix of commercial, residential, educational, and cultural uses is essential to creating a socially and functionally dynamic station area (Shirazi, 2020).

A related strategy is the provision of density incentives through increased Floor Area Ratios (FAR) or allowable building heights within 300 to 500 meters of high-capacity transit corridors. This approach is consistent with global best practices (Cervero et al., 2002; Bernick & Cervero, 1997), and has been partially implemented in Tehran's district-level plans (Tehran Detail Plan, 2012). However, without qualitative guidance and land-use integration, density alone can lead to congestion and livability problems. Therefore, density must be linked with public space, access to amenities, and infrastructure capacity (ITDP, 2017). For station areas like HEMAT, targeted density increases - particularly through mid-rise, mixed-use redevelopment - could provide the critical mass needed to support urban vitality and commercial viability.

Another Iran-specific strategy is the reprogramming of institutional and military lands. Tehran's station areas are frequently bordered by parcels owned by the military or other high-security entities, often fenced and inactive. While expropriation is politically sensitive, there is growing precedent for negotiated agreements, shared-use models, or cultural programming that introduces limited public access (Habibi & Maghsoodi, 2018; Tehran Municipality, 2020). This strategy allows for gradual transformation of land without altering legal ownership, balancing national security concerns with the need for civic engagement and urban functionality. In the case of HEMAT Station, activating even a portion of these lands through weekend markets, public events, or temporary installations can catalyze long-term change.

The integration of public realm and transit interface is also critical. Streets and open spaces should be seen as extensions of the transit system, not barriers between land uses and stations. Yet in many parts of Tehran, poor sidewalk conditions, vehicular dominance, and a lack of street amenities discourage walking. International TOD guidelines stress the need for continuous, shaded, and visually connected pedestrian corridors (Gehl, 2010; ULI, 2016). In Tehran, this priority is echoed in urban design codes for key transit corridors (Tehran Detail Plan, 2012), though implementation remains uneven. Around HEMAT, improving east–west pedestrian continuity and transforming dead edges into active frontages would significantly increase connectivity and spatial legibility.

A growing concern in Tehran is the mismatch between TOD infrastructure and housing affordability. While metro access has been shown to increase land value, it also contributes to displacement of lower-income groups unless corrective policies are adopted (Shakouie & Hashemi, 2017). TOD-based strategies increasingly call for transit-proximate housing that includes subsidized or short-term rental options, particularly for students, service workers, or employees of nearby institutions. These models have been discussed in national housing policy reforms and are aligned with international experiences in equitable TOD (Suzuki et al., 2013). Around HEMAT, such housing could be integrated into institutional land or developed as part of mixed-use incentives.

Finally, the anchoring of civic services in TOD nodes serves both symbolic and functional purposes. The inclusion of micro-scale public facilities - such as health booths, community libraries, cultural kiosks, or digital government services - can humanize and activate station surroundings (Mehta, 2014). These services are small enough to fit within redevelopment projects or public plazas but meaningful enough to create place identity and attract foot traffic. In HEMAT, where there is little public engagement infrastructure, these civic anchors could serve as essential elements in the gradual transformation from institutional isolation to social inclusion.

Together, these strategies reflect a growing recognition that TOD in Iran must go beyond spatial metrics and respond to institutional realities, urban governance structures, and behavioral patterns. The land-use interventions proposed in this thesis for HEMAT Station apply these principles in a context-sensitive manner, offering a replicable framework for similar underperforming station areas across Tehran.

6.3 Proposed Redesign Strategies for Case Station

The redesign of the Hemat Station area is organized through the integrative framework of **Place–Function–Design**, which allows a comprehensive and context-sensitive approach to improving spatial performance, land-use integration, and physical form. Each set of interventions corresponds to one component of the framework, responding to both the analytical findings of this thesis and the broader urban development challenges present in Tehran’s TOD context.

6.3.1 Scenario Development for HEMAT Station

The future vision for the Hemat Station area is structured around a phased, context-sensitive transformation strategy that aligns with TOD principles and local spatial conditions. Key scenario components include:

- **Reprogramming of Institutional Lands**: Strategically converting fenced and underutilized institutional properties into publicly accessible civic spaces, such as cultural centers, event plazas, or community service facilities, through negotiated agreements and shared-use models.

- **Development of Mixed-Use Corridors**: Introducing mid-rise, mixed-use building typologies along primary pedestrian routes, combining residential, commercial, and civic functions to foster round-the-clock activity and local economic vitality.
- **Transit Plaza Integration with Open Space**: Redesigning the station forecourt as a multifunctional transit plaza that seamlessly connects to an adjacent public park or green event space, enhancing both spatial legibility and environmental quality.
- **Enhanced Pedestrian Connectivity**: Establishing safe, legible, and continuous east–west pedestrian linkages across institutional barriers and major roadways through new crossings, permeable paths, and accessibility upgrades.

6.3.2 Key Spatial Interventions

PLACE

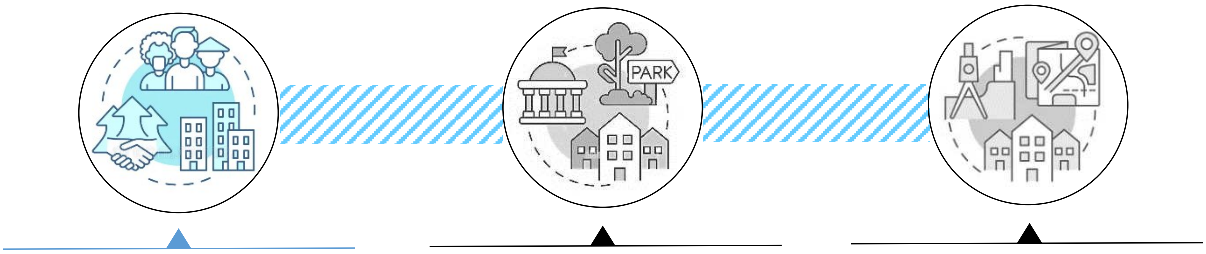
Creating a sense of place is fundamental to successful TOD, particularly in station areas where institutional land use and physical fragmentation have produced visually and functionally disconnected environments.

FUNCTION

While physical access is critical, land use functionality determines whether station areas are lively, inclusive, and consistent with TOD principles. In the case of Hemat, the overwhelming presence of mono-functional, low-density institutional buildings hinders vibrancy.

DESIGN

Design mediates how space is perceived, navigated, and inhabited. While land use and spatial anchoring determine structural logic, design features activate and humanize these environments.



PLACE: Spatial Anchoring and Identity

1. Forecourt Plaza Redesign

The current station entrance suffers from spatial ambiguity, inactive frontages, and a lack of urban comfort. This proposal calls for the transformation of the entry zone into a welcoming urban gateway, featuring shaded seating, well-defined edges, and active ground-floor functions such as kiosks or cafes. By enhancing visual coherence and usability, the redesigned forecourt would anchor the station spatially and symbolically, promoting its identity as a civic space.

2. East–West Spatial Reconnection

The institutional walls and restricted-access plots to the south and east of the station create major barriers to continuity and movement. This intervention introduces permeable pedestrian paths across or alongside these barriers, supported by lighting, signage, and urban art installations. Such paths would reconnect urban blocks, strengthen street legibility, and enable smoother pedestrian flow, fulfilling the spatial integration goals of TOD.

3. Green Mobility Belt

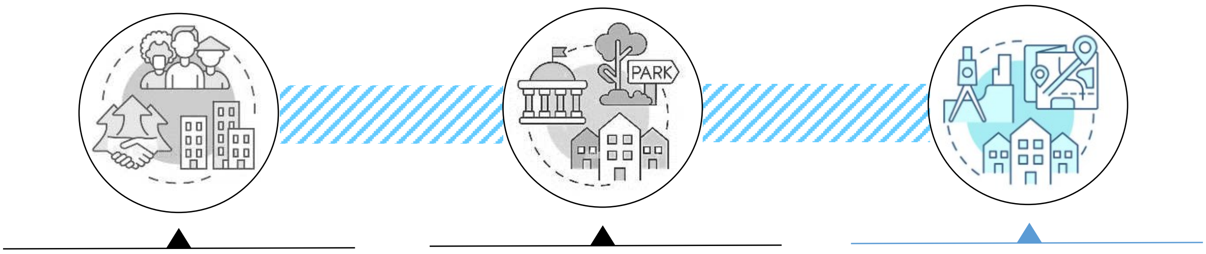
The western edge of the station is currently dominated by a highway and underused green strips. This intervention reimagines that boundary as a linear green mobility corridor, including shaded paths for walking and cycling, public seating, and stormwater-sensitive landscaping. This strategy would not only buffer the highway's negative impacts but also establish a meaningful green link between the station and nearby urban destinations.

FUNCTION: Land Use Reprogramming for TOD Performance

4. Mixed-Use Southern Buffer
The southern buffer zone, currently dominated by low-intensity administrative buildings, is proposed to be transformed into a dense mixed-use development area. This includes mid-rise housing, cultural facilities, and street-level retail, all organized around walkable blocks and public spaces. The objective is to introduce a permanent residential population and a critical mass of daily activities, reinforcing the functional role of the station as a neighborhood anchor.

5. Distributed Micro-Service Nodes
A second strategy involves the spatial distribution of micro-scale civic and commercial facilities - such as health booths, digital kiosks, mobile book cafés, and co-working pods - along primary pedestrian corridors. These elements bring services closer to users, increase ground-floor activity, and offer opportunities for informal social interaction. Their modular nature makes them suitable for temporary or pilot-phase installations, especially in spaces with limited buildability.

6. Short-Term Housing Overlay
Recognizing the station's proximity to institutional employment centers, this intervention proposes a short-term housing program (e.g., dormitories or modular apartments) targeted at public employees, students, or transit workers. Implemented via public-private agreements on underused state land, this strategy introduces round-the-clock use and improves the station's human presence without requiring full-scale housing redevelopment.



DESIGN: Form and Experience Enhancement

7. Ground Floor Activation of Institutional Buildings

Many buildings surrounding Hemat Station feature blank or underused ground floors. This proposal recommends retrofitting these facades with small commercial or service uses such as food vendors, print shops, or parcel lockers. These low-cost interventions dramatically increase pedestrian engagement and support functional diversity at the street level - both hallmarks of effective TOD.

8. Wayfinding and Urban Furniture Enhancement

Navigation and comfort in public space are essential to TOD usability. This intervention includes the installation of clear wayfinding elements, seating, tactile paving, lighting, and water fountains. These additions improve spatial legibility, encourage walkability, and make the environment more inclusive - especially for children, seniors, and people with disabilities.

9. Inclusive Pedestrian Bridge

The physical division caused by the adjacent highway presents a serious barrier to station access. A key proposal is the recreate of a universally designed pedestrian bridge, equipped with ramps, shading elements, and security lighting. This intervention prioritizes safe and dignified access for all users and symbolizes the reintegration of the station area with the wider urban fabric.

Figure 24 HEMAT station's Land use before interventions

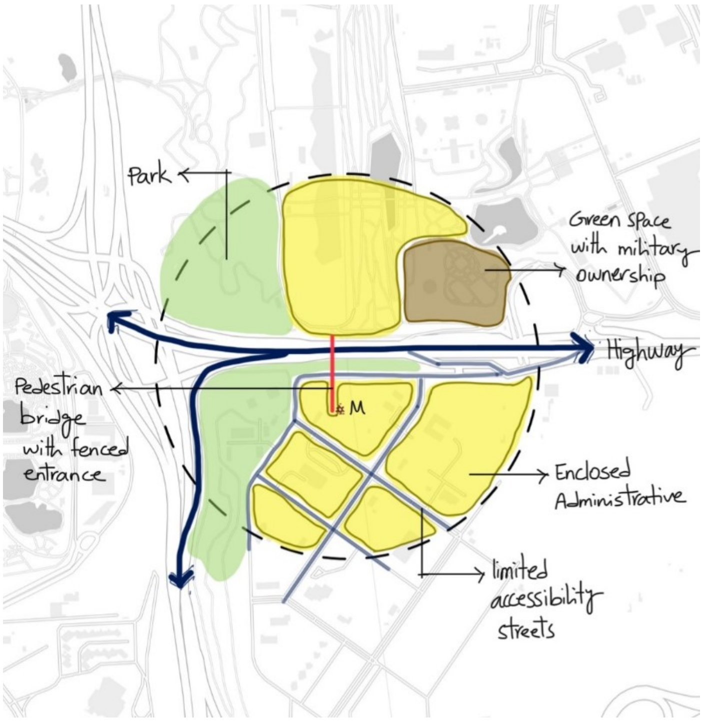


Figure 25 HEMAT station's Land use after interventions

6.4 Evaluation of Interventions

The interventions proposed for Hemat Station have been comprehensively evaluated using the Place–Function–Design (PFD) framework, in alignment with Tehran's institutional constraints and spatial challenges. This multi-layered assessment reflects how each intervention addresses the research objectives and hypotheses outlined in the thesis, while enhancing TOD performance at the station-area scale.

From a Place perspective, the interventions target the spatial fragmentation and lack of civic identity that characterize the current station context. A redesigned forecourt plaza and a new pedestrian-oriented service mall near the station entrance aim to establish a vibrant and legible arrival space. To reconnect severed urban fabrics, an inclusive pedestrian bridge extends across the highway, integrated with a green mobility belt and walkable access routes. These strategies collectively enhance spatial coherence and east–west pedestrian permeability, which directly support Objective 1 and test Hypothesis 3 concerning the impacts of spatial disconnection on TOD outcomes.

In terms of Function, the area's initial condition - marked by zero population density and a complete absence of residential uses - necessitated the introduction of mid-rise apartment buildings and temporary student housing within the southern buffer. Additionally, mixed-use overlays combining residential, commercial, educational, and cultural functions have been proposed to promote land-use diversity and active street life. As part of this transformation, fenced one-story government offices have been consolidated into a vertical administrative complex to free up land and allow for more efficient programming. Restricted institutional zones to the north of the highway have been repurposed into accessible cultural and religious facilities. These proposals directly respond to Hypothesis 1, confirming that introducing diverse and inclusive programs within a 500-meter buffer of the station can help convert low-productivity lands into transit-supportive urban fabric, in alignment with the National TOD Guideline (2020) and the Tehran Comprehensive Plan (2007).

On the Design dimension, a series of user-centered improvements focus on accessibility, safety, and comfort. These include ground-floor activation through street-level retail, inclusive public furniture, universal wayfinding, and human-scale lighting - all designed to improve the pedestrian experience and visual continuity. A safe and inviting pedestrian bridge links both sides of the station, while integrated cycling infrastructure is embedded within existing green parks and neighborhood connectors. These measures support Objective 3 and validate Hypothesis 2, which posits that TOD performance improves when inclusive and well-articulated design elements bridge the gap between infrastructure and urban life.

Taken together, these interventions address Hemat Station's most critical deficits: institutional inaccessibility, lack of residential presence, mono-functionality, and spatial discontinuity. By applying the PFD framework to guide design logic, the strategy aligns with national and municipal TOD policies while proposing realistic, phased transformations. Anticipated impacts include increased land-use productivity, enhanced walkability, improved public space quality, and higher ridership potential - essential elements for building a replicable and policy-compliant TOD model in Tehran.

PFD Dimension	Intervention	TOD Principle Addressed	Iranian Policy Alignment
Function	Mixed-use overlays (residential, cultural, commercial, educational)	Functional Diversity	Tehran Comprehensive Plan (2007); TOD National Guideline (2020)
Function	Micro-service nodes (kiosks, booths, pods)	Functional Diversity	TOD Pilot Studies Report (2020); Municipal Micro-Service Models
Connectivity	Green mobility belt & pedestrian bridge	Spatial Connectivity	Tehran Detail Plan (2012); National TOD Guideline (2020)
Connectivity	East–west permeable pathways and crossings	Spatial Connectivity	Tehran Municipality Urban Regeneration Guidelines
Design	Ground-floor activation and street-level retail	Design Quality & Walkability	National TOD Design Manual; ITDP TOD Standard (adapted)
Design	Urban furniture, wayfinding, universal access	Inclusivity & Comfort	Iran's Barrier-Free Design Guidelines (2021); Tehran TOD Design Codes
Governance	Shared-use agreements with institutional landowners	Institutional Flexibility	National TOD Guideline (2020); Tehran Urban Cooperation Models

Table 11 Alignment of Proposed TOD Interventions with PFD Dimensions and National Policy Frameworks by author

This framework reveals that the interventions proposed in Chapter 6 collectively enhance Hemat Station's performance across all major TOD dimensions - from structural access and mobility to land-use diversity.

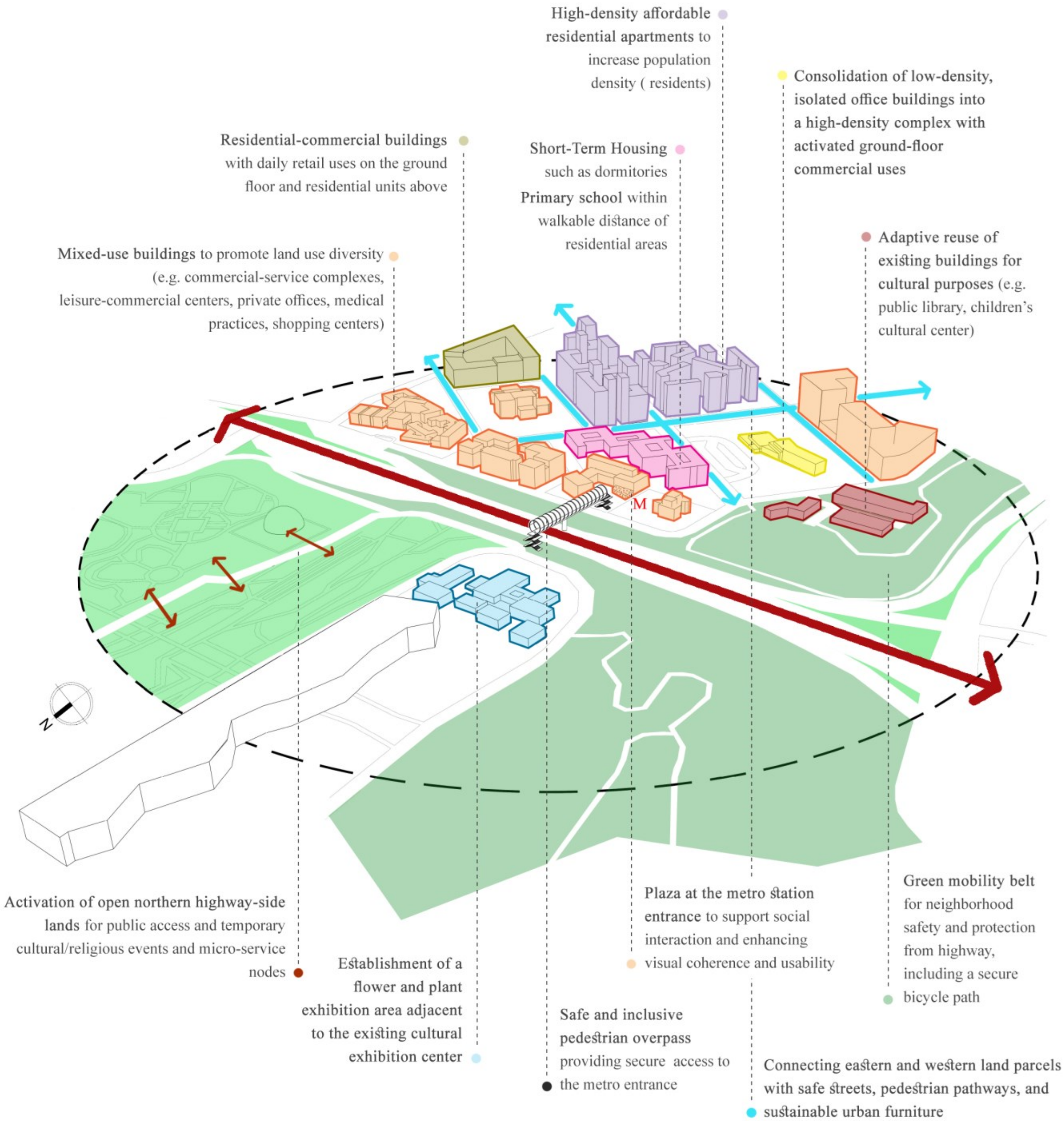


Figure 26 3D visual of interventions in HEMAT station by author

Chapter 7
Conclusion / Recommendations

7.1 Summary of Key Findings

This research evaluated the current state of Transit-Oriented Development (TOD) around Tehran's metro stations, identifying spatial, institutional, financial, and socio-cultural barriers to its successful implementation. Key findings include:

1. Spatial Distribution of TOD Performance

The composite TOD performance map revealed stark spatial inequalities across Tehran's metro network. Stations in central and northern districts - typically near commercial hubs and existing mixed-use neighborhoods - displayed higher TOD scores. In contrast, stations located in southern and peripheral zones, particularly along Lines 1 and 3, consistently underperformed. These areas exhibited limited land use diversity, low population and employment densities, and fragmented pedestrian access, reducing their potential to function as transit-oriented nodes.

2. Indicator-Based Weaknesses

Density: More than 60% of metro stations fall below TOD-supportive density thresholds, particularly in the south and southeast of the city. These low-density patterns weaken the rationale for high-capacity transit and reduce pedestrian activity around stations.

Diversity: Land use entropy analysis revealed that over 70% of station areas are dominated by single-use zoning, especially residential or industrial. This lack of functional mixing limits round-the-clock activity and weakens the socioeconomic vibrancy required for TOD.

Design: Streetscape and walkability analysis highlighted significant design deficiencies in pedestrian networks. Large block sizes, auto-oriented infrastructures, and barriers such as gated communities or highways disconnect many stations from their surroundings - undermining walkability and access.

Destination Accessibility: Fewer than 30% of Tehran's metro stations offer 10-minute walking access to more than two essential services (e.g., healthcare, education, retail). This lack of service integration discourages reliance on public transit and reduces local utility of station areas.

Distance to Transit: While theoretical catchment buffers are consistent across the system, physical barriers - walls, fences, dead-end streets - substantially reduce actual accessibility to many stations. Notably, HEMAT and Shahid Bagheri stations demonstrate serious access issues due to disconnected street patterns and built form constraints.

3. Governance and Policy Barriers

Institutional fragmentation across Tehran's planning and transit agencies creates misaligned priorities and poor implementation. Zoning laws remain rigid and outdated, while financial tools to support TOD (e.g., value capture, density bonuses) are largely absent. Public-private cooperation is minimal, and station area redevelopment remains heavily underfinanced.

4. Socio-Cultural and Behavioral Challenges

Public preferences continue to favor low-density, car-dependent lifestyles, especially among middle- and upper-income groups. The cultural resistance to high-rise living and reliance on private cars persists, despite the presence of extensive metro infrastructure. Public awareness of TOD benefits remains low, further limiting political and community support for such initiatives.

7.2 Answering Research Questions

This section synthesizes how the research findings addressed the main research questions, drawing broader implications without repeating the detailed results already covered.

What are the existing land use patterns around Tehran's metro stations, and how do they align with TOD principles?

The land use patterns observed around most stations reflect a legacy of car-oriented urbanism. Their low density, functional uniformity, and weak pedestrian infrastructure reveal not just a technical gap but a conceptual one: TOD principles have yet to influence land use governance in any substantial way. Effective TOD in Tehran will only become possible when planning shifts from reactive zoning to proactive integration of transit and land development.

What are the institutional and regulatory challenges preventing effective TOD implementation?

The lack of alignment among urban planning, transport authorities, and financial mechanisms is not merely administrative - it signals a structural weakness in metropolitan governance. The research points to a clear need for institutional reforms that go beyond project coordination, enabling truly integrated planning frameworks, responsive zoning codes, and mechanisms that link infrastructure investment to land value returns.

How do socio-cultural and financial factors affect TOD implementation?

TOD's failure in Tehran is not due to spatial constraints alone. Deep-seated preferences for low-rise, automobile-based living - combined with risk-averse development culture and inadequate funding instruments - have weakened both public demand and private sector engagement. Changing this trajectory requires not only infrastructure investment, but also cultural and behavioral shifts supported by awareness campaigns and market incentives.

What land use strategies can support TOD in Tehran?

Rather than prescribing a universal solution, the study suggests that TOD in Tehran must be built incrementally - through tailored interventions at station level, flexible zoning tools, and partnerships that align public and private interests. But technical tools alone are not enough: the true enabling factors lie in governance reform, visionary leadership, and sustained public engagement.

7.3 Policy Recommendations for TOD Implementation in Tehran

To facilitate effective TOD in Tehran, the following policy and planning recommendations are proposed:

A. Spatial and Urban Design Interventions

- Prioritize infill development and densification around low-performing stations, especially in southern districts.
- Redesign street networks and public spaces to eliminate physical barriers to access (e.g., remove dead-end alleys, improve intersection density).
- Introduce mixed-use overlays and adaptive zoning around stations like HEMAT to enable 24-hour activity and service diversity.

B. Regulatory and Institutional Reforms

- Adopt form-based codes and flexible land use policies for transit catchment areas.
- Establish a central TOD implementation unit within the Tehran Municipality to coordinate between agencies.
- Reform zoning to permit vertical land use integration - such as residential-over-retail models - within 500–800m of metro nodes.

C. Financial Tools and Investment Incentives

- Implement land value capture mechanisms to reinvest in TOD infrastructure.
- Create density bonus schemes and tax abatements for private developers undertaking TOD-compatible projects.

- Facilitate PPP models to finance station area upgrades, especially in low-demand or high-risk districts.

D. Enhancing Accessibility and Connectivity

- Design continuous pedestrian corridors and upgrade sidewalks, crosswalks, and public lighting near stations.
- Expand last-mile mobility options, such as bicycle lanes and shared mobility hubs.
- Ensure all station areas meet a minimum threshold for access to essential services within a 10-minute walk.

E. Public Engagement and Awareness

- Conduct public campaigns to raise awareness of TOD's social and environmental benefits.
- Include community stakeholders in station area planning processes to ensure locally accepted outcomes.
- Develop equity-focused TOD strategies, such as inclusionary zoning and affordable housing near transit.

7.4 Recommendations for Future TOD Research and Development

To advance the implementation and effectiveness of Transit-Oriented Development (TOD) in Tehran, future research must build on the findings of this thesis and address critical gaps through deeper, broader, and more innovative inquiry. The following areas are particularly important:

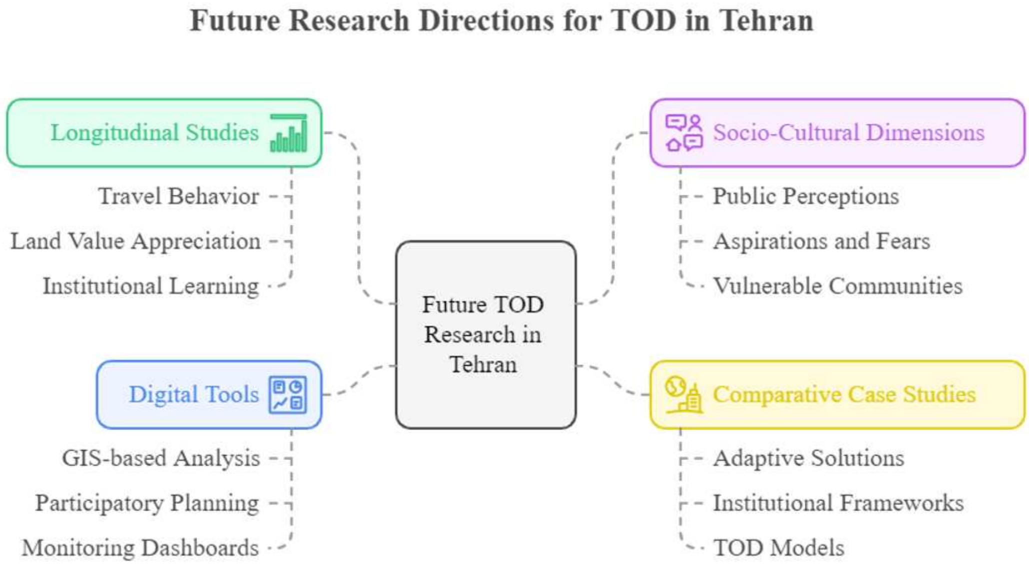


Figure 27 Future research direction for TOD in Tehran by author

1. Conduct Longitudinal Studies to Monitor TOD Impacts Over Time

While this study provides a cross-sectional assessment of TOD indicators, it does not capture how interventions evolve or perform over extended periods. Longitudinal research is essential to:

Track changes in travel behavior - such as shifts from private vehicle use to public transit - as TOD strategies (e.g., pedestrian improvements, densification) are implemented.

Measure land value appreciation around upgraded metro stations, which is a common effect of successful TOD. Tracking these trends helps assess financial feasibility and equity outcomes (e.g., displacement risks or gentrification).

Evaluate institutional learning and policy adaptation - by observing how regulatory changes, urban design interventions, or governance reforms evolve and impact TOD implementation across political cycles.

By gathering data at regular intervals (e.g., annually), such studies can generate a feedback loop that allows planners and policymakers to refine TOD strategies in real time.

2. Explore Socio-Cultural Dimensions of TOD Adoption

One of the major constraints to TOD in Tehran is the mismatch between TOD principles and prevailing cultural values or lifestyle preferences. Future research should delve into the social and psychological dimensions of urban form and mobility choices, specifically:

Investigate public perceptions of density, mixed-use environments, and vertical living, especially among different income and age groups.

Examine the aspirations, fears, and resistance associated with TOD-related changes, such as reduced car use, smaller housing units, or neighborhood densification.

Focus on vulnerable and marginalized communities, such as low-income households, women, and elderly residents, to understand how TOD can improve or potentially harm their access to opportunities and services.

Understanding these socio-cultural variables will make TOD more context-sensitive and inclusive, ensuring that TOD policies resonate with everyday life experiences in Tehran.

3. Conduct Comparative Case Studies from the Global South

Many of the challenges Tehran faces - such as fragmented governance, informal development, weak land markets, and limited public participation - are common in other Global South cities. By studying comparative TOD models in cities like Bogotá, Jakarta, Mumbai, or Cairo, future research can:

Identify adaptive solutions to shared challenges, such as financing TOD without full market liberalization or promoting walkability in informal settlements.
Analyze the institutional frameworks and political strategies that have enabled or blocked TOD in similarly constrained environments.
Develop a typology of TOD models suitable for the Global South, moving beyond Western paradigms to propose realistic and scalable solutions for Tehran.
Such comparisons will enhance policy transferability and inspire more practical, regionally appropriate TOD pathways.

4. Develop Digital Tools for TOD Planning, Monitoring, and Co-Design

The complexity of TOD implementation requires real-time data integration, predictive modeling, and inclusive design processes. Future research should support the development of digital urban planning tools that combine:
GIS-based spatial analysis with mobility data to map TOD performance, identify accessibility gaps, and simulate impacts of zoning changes or new developments.
Participatory planning platforms that engage citizens in station area redesign through online feedback systems, digital surveys, or visual preference tools.
Monitoring dashboards that track key TOD indicators (e.g., density, land use mix, service access) over time, allowing municipalities to quickly assess the success of interventions.
By integrating data science and digital engagement, Tehran can move toward evidence-based, transparent, and participatory TOD planning - critical elements for public trust and long-term success.

Appendix

Normalized TOD Indicator Values for All Tehran Metro Stations

Station name	DIVERSITY		DENSITY		DESTINATION		DESIGN			DISTANCE		Find Weight
	SHANNON	ENTROPY	POP_DENSITY	FAR	Accessibility to Urban Services (Service Count)	SERVICE AREA ANALYSIS	Walkability Index	road network connectivity	side walk coverage	Multimodal Connectivity	Last Mile to POI	
EBN E SINA	0.53	0.56	0.58	0.43	0.11	0.49	0.12	0.77	0.68	0.54	0.77	0.35
ERAM SABZ	0.43	0.66	0.33	0.54	0.01	0.13	0.01	0.24	0.36	0.50	0.00	0.16
AZADEGAN	0.87	0.67	0.09	0.00	0.03	0.27	0.05	0.06	0.18	0.54	0.55	0.13
OSTAD MOEIN	0.78	0.65	0.41	0.50	0.07	0.60	0.09	0.43	0.56	0.68	0.75	0.30
ASHRAFI ISFAHANI	0.72	0.70	0.53	0.46	0.06	0.73	0.06	0.37	0.48	0.52	0.74	0.30
AQDASIYEH	0.72	0.59	0.14	0.45	0.02	0.44	0.03	0.34	0.26	0.52	0.62	0.19
IMAM HOSSEIN	0.68	0.55	0.57	0.37	0.22	0.90	0.57	0.97	0.83	0.71	0.69	0.57
AMIRKABIR	0.65	0.62	0.66	0.39	0.15	0.86	0.15	0.87	0.79	0.56	0.77	0.42
AHANG	0.72	0.47	0.56	0.35	0.11	0.92	0.10	0.63	0.71	0.55	0.42	0.35
KASHANI	0.64	0.77	0.54	0.62	0.07	0.47	0.08	0.50	0.65	0.47	0.54	0.31
IRAN KHODRO	0.30	0.52	0.00	0.22	0.01	0.20	0.01	0.00	0.15	0.49	0.12	0.07
SOHREVARDI	0.62	0.68	0.33	0.72	0.21	0.63	0.24	0.21	0.44	0.73	0.75	0.36
BORJ MILAD	0.43	0.68	0.00	0.68	0.00	0.24	0.00	0.12	0.19	0.65	0.12	0.11
BERYANAK	0.74	0.61	0.66	0.31	0.12	0.21	0.13	0.93	0.76	0.72	0.68	0.37
BASIJ	0.62	0.54	0.23	0.46	0.03	0.19	0.03	0.30	0.29	0.69	0.29	0.17
BESAT	0.79	0.63	0.50	0.21	0.06	0.12	0.06	0.49	0.44	0.70	0.37	0.24
BAHAR SHIRAZ	0.78	0.61	0.46	0.63	0.09	0.77	0.10	0.70	0.50	0.51	0.67	0.35
BAHARESTAN/SADI/MELLAT/ IMAM KHOMEYNI	1.01	0.81	0.06	0.48	0.85	0.68	0.76	0.63	0.41	0.99	0.86	0.64
BUOSTAN GOFTOGO	0.72	0.70	0.37	0.50	0.02	0.18	0.01	0.33	0.31	0.63	0.33	0.19
BUOSTAN LALEH	0.86	0.62	0.09	0.73	0.07	0.59	0.07	0.55	0.25	0.71	0.85	0.26
BIME	0.31	0.27	0.10	0.25	0.01	0.36	0.01	0.17	0.22	0.72	0.57	0.13
PAYANEH JONOB	0.62	0.42	0.01	0.10	0.03	0.15	0.03	0.24	0.16	0.76	0.38	0.11
PIRUOZI	0.42	0.45	0.40	0.38	0.07	0.52	0.05	0.62	0.36	0.54	0.69	0.26
TAJRISH	0.74	0.59	0.28	0.44	0.18	0.75	0.22	0.63	0.46	0.54	0.66	0.35
TEHRANPARS	0.62	0.52	0.54	0.50	0.04	0.49	0.04	0.21	0.43	0.54	0.47	0.25
TEATRE SHAHR	0.97	0.75	0.22	0.72	0.17	0.77	0.17	0.50	0.48	0.72	0.86	0.36
JANBAZAN	0.50	0.44	0.55	0.42	0.13	0.83	0.14	0.64	0.76	0.74	0.66	0.37
JAVADIEH	0.52	0.55	0.58	0.27	0.15	0.01	0.13	0.85	0.72	0.68	0.26	0.32
JAVANMARD GHASAB	0.77	0.67	0.06	0.17	0.02	0.00	0.01	0.26	0.17	0.76	0.26	0.11
40TAN DOLAB	0.63	0.57	0.72	0.33	0.15	0.80	0.17	0.88	0.96	0.53	0.70	0.44
CHITGAR	0.52	0.80	0.00	0.07	0.01	0.11	0.01	0.13	0.19	0.50	0.23	0.08
HASAN ABAD	0.99	0.75	0.25	0.48	0.19	0.71	0.24	0.82	0.44	0.78	0.75	0.39
HOSSEIN ABAD	0.62	0.43	0.14	0.39	0.01	0.36	0.02	0.32	0.17	0.46	0.58	0.16
KH. ABDOLAH ANSARI	0.67	0.65	0.44	0.41	0.11	0.17	0.10	0.58	0.77	0.40	0.65	0.30
IMAM ALI UNI.	0.64	0.66	0.30	0.46	0.06	0.28	0.05	0.65	0.35	0.63	0.63	0.24
TARBIAT MODARES UNI.	0.69	0.76	0.19	0.50	0.04	0.28	0.01	0.55	0.51	0.75	0.70	0.23
SHARIF UNI./ SHADMAN/ DR. HABIB	0.86	0.73	0.41	0.40	0.23	0.62	0.43	0.68	0.60	0.75	0.69	0.46
ELM O SANAT UNI.	0.45	0.62	0.60	0.40	0.13	0.44	0.14	0.54	0.55	0.53	0.59	0.33
DARVAZEH SHEMIRAN	0.75	0.62	0.43	0.40	0.19	1.00	0.23	0.81	0.73	0.53	0.83	0.43
DR. SHARIATI	0.62	0.55	0.34	0.56	0.11	0.79	0.12	0.51	0.54	0.51	0.61	0.32
RAH AHAN	0.63	0.75	0.31	0.25	0.11	0.63	0.11	1.00	0.46	0.81	0.65	0.32
RUODAKI	0.48	0.54	0.84	0.51	0.15	0.09	0.14	0.88	1.00	0.77	0.64	0.41
ZAMZAM	0.61	0.56	0.36	0.23	0.12	0.14	0.09	0.71	0.68	0.74	0.04	0.25
SABALAN	0.37	0.32	0.85	0.37	0.22	0.88	0.24	0.77	0.91	0.53	0.65	0.47
SARSABZ	0.41	0.35	0.58	0.46	0.13	0.52	0.16	0.55	0.66	0.54	0.58	0.34
SHOHADAYE KAN	0.45	0.52	0.52	0.34	0.09	0.86	0.10	0.53	0.54	0.50	0.62	0.32
SHOHADAYE 7TIR	0.81	0.69	0.48	0.64	0.19	0.81	0.22	0.47	0.52	0.79	0.78	0.40
SHOHADAYE 17SHAHRIVAR	0.53	0.44	0.72	0.34	0.14	0.54	0.15	0.81	0.79	0.76	0.67	0.39
SHAHRE ZIBA	0.57	0.56	0.15	0.58	0.02	0.44	0.08	0.46	0.53	0.47	0.50	0.23
SHAHRAN	0.77	0.69	0.30	0.38	0.05	0.26	0.05	0.39	0.59	0.49	0.35	0.22
SHAHR REY	0.92	0.86	0.32	0.32	0.05	0.30	0.05	0.45	0.37	0.76	0.61	0.24
SHAHRAK AZMAYESH	0.74	0.79	0.38	0.63	0.08	0.10	0.10	0.53	0.64	0.72	0.44	0.28
SHAHRAK OKBATAN	0.54	0.61	0.34	0.18	0.01	0.42	0.01	0.16	0.31	0.55	0.43	0.16
SHAHRAK SHARIATI	0.94	0.83	0.34	0.25	0.16	0.28	0.16	0.54	0.52	0.73	0.42	0.30

SH. ARMAN ALIVERDI	0.50	0.57	0.19	1.00	0.02	0.54	0.02	0.18	0.25	0.48	0.47	**0.21**
SH. BAGHERI	0.47	0.44	0.42	0.41	0.06	0.39	0.05	0.23	0.42	0.44	0.74	**0.23**
BOKHARAYI	0.62	0.54	0.60	0.24	0.17	0.53	0.49	0.99	0.77	0.65	0.63	**0.50**
SH. BEHESHTI/ SH. MOFATEH	0.93	0.61	0.15	0.85	0.25	0.58	0.21	0.27	0.26	0.82	0.84	**0.34**
SH. HAQANI	0.48	0.63	0.00	0.33	0.01	0.18	0.00	0.13	0.00	0.49	0.16	**0.08**
SH. DADMAN	0.62	0.61	0.18	0.73	0.03	0.41	0.03	0.26	0.34	0.51	0.47	**0.20**
SH. REZAYI	0.83	0.50	0.74	0.20	0.32	0.91	0.06	0.98	0.89	0.56	0.83	**0.45**
SH. ZEYNODIN	0.45	0.43	0.33	0.47	0.04	0.25	0.04	0.40	0.55	0.50	0.54	**0.22**
SH. SATARI	0.68	0.59	0.60	0.66	0.03	0.16	0.03	0.38	0.35	0.30	0.47	**0.25**
SH. SADR	0.77	0.68	0.25	0.77	0.06	0.48	0.07	0.49	0.54	0.51	0.80	**0.28**
SH. SAYAD SHIRAZI	0.60	0.39	0.29	0.58	0.04	0.32	0.04	0.39	0.45	0.41	0.54	**0.22**
SH. QODUOSI	0.73	0.65	0.27	0.74	0.09	0.58	0.24	0.33	0.30	0.72	0.70	**0.32**
SH. MAHALATI	0.78	0.72	0.11	0.60	0.02	0.47	0.02	0.33	0.38	0.55	0.63	**0.20**
SH. MADANI	0.69	0.56	0.68	0.35	0.14	0.85	0.13	0.95	0.75	0.52	0.81	**0.42**
SH. NAVAB SAFAVI	0.61	0.55	0.79	0.48	0.24	0.73	0.14	0.84	0.88	0.76	0.48	**0.44**
HEMAT	0.28	0.23	0.00	0.16	0.00	0.29	0.00	0.08	0.04	0.45	0.14	**0.06**
SHUOSH	0.81	0.77	0.10	0.13	0.08	0.44	0.03	0.68	0.33	0.73	0.64	**0.21**
SADEQIEH	0.69	0.65	0.33	0.46	0.04	0.13	0.03	0.23	0.33	0.78	0.64	**0.20**
TALEQANI/DOLAT/FERDOSI	0.98	0.73	0.19	0.65	0.47	0.71	0.47	0.55	0.45	0.83	0.88	**0.50**
TARASHT	0.56	0.64	0.45	0.45	0.04	0.42	0.05	0.49	0.39	0.64	0.52	**0.25**
ABDILABAD	1.00	0.80	0.51	0.21	0.22	0.15	0.19	0.42	0.61	0.74	0.44	**0.33**
ALAME JAFARI	0.37	0.33	0.73	0.66	0.05	0.59	0.06	0.42	0.64	0.20	0.57	**0.32**
ALI ABAD	0.66	0.66	0.62	0.28	0.10	0.18	0.09	0.49	0.50	0.53	0.42	**0.28**
FADAK	0.55	0.56	0.78	0.39	0.11	0.46	0.10	0.43	0.57	0.51	0.47	**0.33**
FARHANGSARA	0.82	0.73	0.36	0.32	0.05	0.44	0.04	0.40	0.35	0.51	0.59	**0.23**
MEHR ABAD AIRPORT	0.00	1.00	0.01	0.04	0.00	0.22	0.01	0.37	0.02	0.52	0.00	**0.07**
QAEM	0.74	0.66	0.47	0.23	0.03	0.45	0.02	0.38	0.42	0.47	0.36	**0.22**
QOLHAK	0.67	0.50	0.43	0.56	0.09	0.74	0.11	0.66	0.60	0.52	0.78	**0.34**
QEYTARIEH	0.67	0.59	0.14	0.51	0.04	0.62	0.05	0.39	0.28	0.51	0.69	**0.22**
KARGAR	0.77	0.66	0.34	0.57	0.08	0.55	0.08	0.40	0.38	0.75	0.83	**0.28**
KOMEYL	0.67	0.54	1.00	0.41	0.14	0.23	0.14	0.89	0.86	0.73	0.80	**0.43**
KIANSHAHR	0.67	0.53	0.45	0.13	0.10	0.60	0.10	0.21	0.37	0.40	0.65	**0.25**
MOHAMADIYE	0.97	0.67	0.21	0.24	1.00	0.78	0.99	0.86	0.57	0.77	0.80	**0.78**
MODAFEAN SALAMAT	0.75	0.68	0.35	0.44	0.14	0.18	0.15	0.51	0.49	0.73	0.74	**0.30**
MARZDARAN	0.36	0.37	0.56	0.72	0.05	0.49	0.06	0.41	0.50	0.54	0.56	**0.28**
MOSALA IMAM KHOMEYNI	0.49	0.50	0.07	0.46	0.01	0.22	0.01	0.17	0.09	0.51	0.16	**0.11**
MONIRIEH	0.47	0.40	0.83	0.43	0.11	0.92	0.05	0.90	0.76	0.73	0.84	**0.41**
MAHDIEH	0.78	0.69	0.77	0.35	0.16	0.93	0.52	0.95	0.77	0.74	0.69	**0.57**
MEYDAN AZADI	0.03	0.68	0.00	0.34	0.00	0.29	0.00	0.19	0.22	0.77	0.31	**0.10**
MEYDAN ENQELAN ISLAMI	0.87	0.43	0.19	0.61	0.21	0.63	0.23	0.62	0.47	0.75	0.81	**0.37**
MEYDAN JAHAD	0.74	0.62	0.30	0.78	0.17	0.76	0.19	0.43	0.51	0.69	0.84	**0.36**
MEYDAN HOR	0.55	0.48	0.39	0.48	0.07	0.54	0.06	0.71	0.49	0.74	0.46	**0.28**
MEYDAN SHOHADA	0.65	0.66	0.44	0.44	0.12	0.87	0.14	0.74	0.64	0.55	0.78	**0.37**
SANA'AT	0.65	0.57	0.19	0.56	0.01	0.48	0.01	0.24	0.26	0.83	0.44	**0.18**
MEYDAN QIAM/ MOLAVI	0.80	0.64	0.29	0.14	0.56	0.93	0.84	0.76	0.64	0.79	0.81	**0.65**
KETAB	0.58	0.62	0.34	0.53	0.09	0.79	0.12	0.39	0.47	0.52	0.84	**0.30**
MEYDAN VALIASR	0.85	0.65	0.36	0.92	0.19	0.80	0.20	0.51	0.51	0.81	0.83	**0.40**
MIRDAMAD	0.73	0.63	0.23	0.74	0.08	0.40	0.00	0.20	0.45	0.35	0.79	**0.23**
MIRZAYE SHIRAZI	0.77	0.69	0.11	0.77	0.22	0.65	0.23	0.25	0.46	0.78	0.81	**0.34**
NABARD	0.41	0.37	0.86	0.39	0.16	0.75	0.19	0.41	0.62	0.53	0.72	**0.40**
NEMAT ABAD	0.66	0.59	0.23	0.06	0.11	0.35	0.08	0.42	0.34	0.76	0.11	**0.20**
NOBONYAD	0.52	0.22	0.15	0.78	0.01	0.14	0.01	0.32	0.13	0.52	0.30	**0.15**
NIRUOHAVAYI	0.45	0.39	0.67	0.44	0.13	0.45	0.15	0.38	0.56	0.53	0.75	**0.33**
HARAVI	0.62	0.63	0.19	0.48	0.02	0.19	0.01	0.26	0.19	0.40	0.35	**0.15**
HELAL AHMAR	0.75	0.54	0.72	0.26	0.22	0.88	0.13	0.98	0.78	0.72	0.79	**0.44**
VERDAVAR	0.59	0.94	0.00	0.11	0.00	0.22	0.00	0.22	0.16	0.52	0.11	**0.09**
VARZESHGAH AZADI	0.44	0.60	0.10	0.74	0.00	0.21	0.00	0.20	0.16	0.44	0.08	**0.13**
YADEGAR IMAM	0.57	0.70	0.40	0.67	0.02	0.19	0.02	0.27	0.44	0.49	0.37	**0.21**

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