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CLASSIFICATION OF MASS TRANSIT RAIL STATIONS BASED ON URBAN FEATURES

FARZANEH GHARAATI[1], MOHAMMAD NIKKAR*[2], MOHAMMADALIABADI[3] and AMIN HABIBI[4]

[1] Department of Architecture, Shiraz University, Shiraz, Iran. Email: gharaati@gmail.com
[2, 3, 4] Assistant Professor, Department of Architecture, Shiraz University, Shiraz, Iran.
*Corresponding Author

Abstract

Designing metro stations is one of the research topics for engineers, with the increasing need for large-scale TOD. This paper describes a classification of metro stations based on feature designs by descriptive-analytical method that are divided into six major types based on urban and architectural features. The types differ in alignment level toward the ground, platform geometrical type, urban scale, and performance, adjacent and internal communication. The models for the Railway Metro Station Design and Planning (RMSDP) have been proposed in this paper. Knowing the type of station can be one of the effective solutions to the challenges in urban designing, the architecture of the station, and alignment between context capabilities and station coordination. These categories will significantly help designers to consider the regional, technical, and functional characteristics of each type of metro station to optimize design, increase efficiency and coordinate with the context.

Keywords: TOD, Classification, Design, Metro Station.

1. INTRODUCTION

Metro is the most common name for high-speed transit-oriented systems, all or part of which is underground [1]. Railway stations play a vital role for passengers, non-traveling users and the communities in which they are located. They serve the growing needs of an increasingly mobile population and are used by a wide range of users [2]. Metro stations are no longer a stopover or just a simple platform for urban commuters. The multi-functional and comprehensive design of stations, in addition to efficiency in terms of landscape and culture [3], reduce urban traffic, save parking costs, reduce accidents, save energy and increase job opportunities by increasing activities [4]. According to the goals of sustainable development, the use of green systems for urban transportation, especially the metro station, is one of the practical factors in improving urban quality and achieving a sustainable society. Reducing urban traffic and accidents, energy-saving, increasing job opportunities are achieved by building subway lines in a city, especially densely populated cities with high daily travel. Therefore, high accuracy in the design of metro lines and their urban stations is an essential issue that should be considered more in response to the goals of sustainable development. Designing metro stations in urban planning and management is necessary for the initial steps of setting up urban lines and networks. Major factors such as urban context, public access, population density, soil type, etc are involved in the design of these stations. Accordingly, it is necessary to have a regular framework and rule to determine the factors and subsets of each factor to the design. If the station is not designed following the context in terms of urban planning, not only has it not meeting the needs of passengers and the urban context, but it may also lead to disorder and dissatisfaction of passengers. So the main question in this article is what factors should be considered in designing the initial phases of the metro station with a comprehensive view and to respond to the needs of passengers under the goals of sustainable development? Consequently, in this practical article, to design metro stations in a regular framework and with a comprehensive view and considering the factors involved in architecture and urban planning in the design planning of the metro station in the initial phases of design, first the factors shaping the architectural design of subway stations were identified by referring to authentic scientific sources, dissertations and international guidelines around the world. Then the factors were classified into six general categories. Classification, segregation, and organization of factors involved in the design of metro stations lead to align field capabilities and turn them into a place beyond a simple platform for boarding. Designers and planners will have an easier design process by recognizing and referring to these six categories and their sub-categories in the initial phases of designing metro stations. Finally, for the validity of the studies and classifications presented, Shiraz metro line 1 stations were analyzed as a case study in the existing category, and the potentials or strengths of each station were identified to improve their quality.

2. MATERIAL AND METHODS

The present practical article type with descriptive-analytical through library studies, with th aim of providing a comprehensive approach for designing metro stations in the initial phase of design, classifies the existing metro stations based on the common urban and architectural features between them in terms of alignment level toward the ground, platform geometrical type, urban scale, performance, adjacent and internal communication of the station is discussed. For this purpose, a review and analysis will be implemented by referring to the thesis, some regional metro station design guidelines, scientific articles and books, in the world based on the proposed categories and provide examples. Famous stations of each category have been brought in for a better understanding of the structure, inside or outside the country of Iran. In the second part of the article 20 metro stations throughout line 1, Shiraz, Iran, have been analyzed and some strategies have been presented for restoration and management for better design in the future.

3. LITERATURE REVIEW

To classify metro stations, by referring to the thesis, books, and design guidelines of metro stations in prominent cities of the world, the essential categories and their sub-categories in terms of different aspects were examined (Table 1). After collecting the data, it appears that six specific urban architectural features are generally seen in the categories. These features consist of: platform geometrical type, alignment level toward the ground, the station operation, the scale of the station in the city, the proximity of the station to commercial-administrative and location complexes and how the concourse and the platform are connected.

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Table 1: Summary of necessary features to be considered in the design of metro stations

Researcher or Instructions	Classification required to review	Subcategories	Categorization features	Final Classification
Thesis and books				
BINU B (2007)	shape of the platform	Island and Side, Curvature	Platform Geometrical type	Geometric
	Urban scale	City central, Rail to rail interchange	The scale of the station in the city	Urban Scale
	construction	Underground, elevated, Surface, open cut	Architecture of underground metro stations	Alignment
Sikhumbuzo Mtembu (2008)	Size of the station	MainlineTerminal, Mainline Interchange, Mainline station, Suburban, Rural, Special	The scale of the station in the city	Urban Scale
Cervero & Murakami (2008)	Urban scale	High-Rise Office, High-Rise Residental, Mid-Rise Residental, Large-Scale Residental, Large-Mixed Used	The scale of the station in the city, its service, and the need for lateral spaces	Urban Scale
Salahshoor (2010)	layout of the Concourse and the platform	Different type of positions of Concourse and the platform	how the Concourse and the platform are connected	Internal communication
Igualada (2015)	The layout of the Concourseabove the platform	The concourse above the ground, Concourse inside the ground, Concourse under the ground	the interrelationship between Concourse and platform	Internal communication
Shahabian and Asadi (2016)	Metro station as a multi-function space	Underground commercial complexes inside or near the station	Metro as a station complex or adjacent to commercial-administrative complexes	Adjacent
Johnson (2020)	Subway stations	Waffle, arch 1, arch 2, and twin-tube	Architecture of underground metro stations	Alignment
	Above ground metro stations based on the shape of the canopy	Gull 1, Gull 2, Alexandria Peak, General Peak, High Peak, Tyson Peak, Gambrel, and Uniques	Architecture of above-ground subway stations	Alignment
Design Guidelines				
Washington (2008)	The function of the station	Core Stations, Mid-Line, Terminus	How the station works	Functional
India (2009)	Platform layout	Island Platforms, Two Side Platforms, Stub Terminal, Flow-Through Platforms	Platform Geometrical type	Geometric
Florida (2013)	Urban scale	Airport/Seaport, key, middle	The scale of the station in the city, its service, and the need for lateral spaces	Urban Scale

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Queensland (2010)	Platform layout	Bay Platforms Two Side Platforms and Split-Level Platform Stations	Platform Geometrical type	Geometric
	Surface stations in terms of shading	One-way, two-way, and two-way separate	Architecture of subway stations located on the ground	Alignment
Winnipeg (2011)	Urban scale	Urban center, urban neighborhood, town center, neighborhood medium density, neighborhood low density, high-frequency transit corridor	The scale of the station in the city, its service, and the need for lateral spaces	Urban Scale
Denver (2014)	TOD Urban typologies	Downtown, Urban center, General Urban, Urban, Suburban	The scale of the station in the city and how it is serviced and the need for ancillary spaces	Urban Scale
Washington (2014)	the shape of the platform	Center Platform, Side Platform, Dual Chamber, Twin Platform Width at Triple Track	Platform Geometrical type	Geometric
Mineta (2015)	the shape of the platform	center and side platforms	Platform Geometrical type	Geometric
Washington (2018)	Alignment	At-grade, Elevated and underground	State of positioned relative to the ground	Alignment
	Station Platform Layout	Center, Side, Split, Flow-through,	The scale of the station in the city and how it is serviced and the need for ancillary spaces	Urban Scale
	The architecture of underground stations	With an arched and flat roof	Architecture of underground metro stations based on the type of excavation	Alignment
	access	Node Value, Place Value, and Market Potential Value	How the station works	Functional
Swiss (2018)	Platform Geometrical type	One Side platform, Two Side Platforms, central and Split-Level Platform	Platform Geometrical type	Geometric
India (2018)	Alignment	Elevated (Based on different Sizes), Under Ground (Based on different Sizes)	Different types of Elevated and Under Ground stations	Alignment
Delhi (2019)	Alignment	At-grade, Elevated and underground	State of positioned relative to the ground	Alignment

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According to the purpose of the research, the classification of metro stations, and the studies conducted (Table 1), based on the common urban and architectural features between the stations, the final classifications are in the form of six categories, geometric, urban scale, functional, adjacent and internal communication. Each metro station can be placed in each category based on the conditions. In the present article, after determining the six categories, the characteristics and division of each category will be described (Table 2).

Table 2: Six primary types of methods are used for feature selection in the classification

Category	Number of subcategories	inventory description	Context Information required for designing
Alignment	3	Status of the station toward the ground	Traffic situation, excavation Soil type, Natural barriers, The situation concerning the historical context, Sidewalk width, noise level
Geometric	4	Geometrical type of platform	Excavation volume and depth Passenger access
Urban Scale	4	Service scale of station in the city and ancillary spaces	Position of a station in the city, Serving the around, Other public transport Neighborhood use such as commercial, office, or parking, Service radius
Function	3	How the station works	Network of the whole lines
Adjacent	3	Station as a complex or adjacent to commercial-administrative complexes	Location of complexes toward the station, Station requirements
Internal Communication	3	how the Concourse and the platform are connected	Alignment, Urban scale, Soil type Depth, Network of urban facilities

4. RESULTS

4.1 Alignment features

The alignment level of metro stations is about their status toward the ground. Which has a subset including underground, aboveground and elevated (Table 3).

4.1.1 Underground Stations (UG)

These stations are created in the heart of cities due to economic issues or dealing with the problem of traffic and air pollution. These stations are entirely underground and include deep, semi-deep and shallow stations. Usually, there are differences in the way they are implemented. In these stations, their only entrances are on the ground. After detecting and entering it, the passenger performs all the necessary movements and actions to reach the train underground and finally gets on the train [5]. Most subway stations run underground. London Canary Warf Station [6] and Tehran Tajrish station [7] are examples of this type. In some sources, different types of architecture of underground metro stations are considered to be due to the way it is drilled. Types of drilling of subway stations are in the form of cut and cover, traditional tunneling, Austrian (NATM), with tunnel drilling machine (TBM), on-site tunnel [8].

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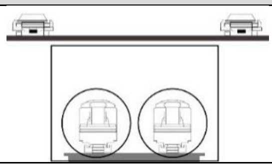
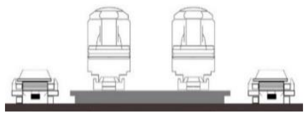
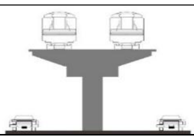
4.1.2 Aboveground Stations (AG)

Unlike underground stations, aboveground Stations metro stations are built on the ground and are visible. These stations do not have some problems with underground construction phases. Therefore, their design and structure will be simpler. Also, this type doesn't have problems such as construction limitations, computational, mechanical, and electrical installations problems [5]. In general, the construction of an underground or above-ground metro station counts as complex planning. It is due to factors such as environmental protection, crossing natural barriers, protection of historical heritage, land acquisition problems, public opinion, and media, creating more space in pedestrian level depends on less impact of construction on traffic and noise level. Factors such as increased economic activity, urban potential, and cost (due to technological developments) have no bearing on the choice of being aboveground or underground [9]. Rowe Street Washington Metro Station and Mashhad National Park [10] are examples of this type. In some sources, different types of aboveground architecture have classified on the shape of their canopy which are one-way, two-way, and two-way separated [8].

4.1.3 Elevated Stations (EL)

The metro station is built from prefabricated columns, usually ten meters above the ground, in the shortest possible time and has minimal traffic. These types of stations are built to cross bridges, rivers, and valleys, when the soil is unsuitable and when it is not possible to go underground or even aboveground. The advantages of this type are the least amount of destruction and having natural light and ventilation. Restrictions on the space of the station itself, distortion of the street view, having visual and noise pollution for adjacent buildings, cutting down trees in the context, and unavailability of all parts of the building in case of emergency are among the disadvantages of these stations [11]. Dubai World Trade Station is an example of this type of station [12].

Table 3: Alignment Classification (Source: Authors)

Station code	Types of station	Subcategoreis	diagram	Case study
UG	Underground	Shape of the roof: Flat, Arch Depth: Deep, Semi-deep, Shallow		“Canary Wharf London” and “Tajrish Tehran”
AG	Aboveground	One way Two Ways Separate two-sided		“Washington Rhode island avenue” and “Mashhad National Park”
EL	Elevated	no subcategory		Dubai World Trade Station

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4.2 Geometric Features

The geometric features of metro stations are about the geometric shape of the platform. Which is including Center Platforms, Two Sides Platforms, Split-Level Platform, Stub Terminal, Flow-Through Platforms, Bay Platforms, One Side platform and Mixed Platforms (Table 4).

4.2.1 Island Platforms (I)

In general, in conventional projects, the use of central platforms is the most preferable platforms located between the trains [5] [13]. In determining emergency exit capacity, each platform can operate and unload two trains simultaneously [13]. In this case, conditions such as easy circulation of passengers, lower station costs, and increased level of safety are provided. Because all passengers are gathered in one platform, a single safety system is needed [5]. "Shahid Kolahdooz" Station in Tehran is the first example of a central station in Iran [14].

4.2.2 Two side Platforms (TS)

If the platform is placed on one side overlooking the line, the platform is of the two side type [20]. In this case, the passenger must determine the direction of the platforms before descending to it [13]. First Phase stations of Shiraz metro line1 are such examples of this type [15].

4.2.3 Split-Level Platform Stations (SL)

Split-level platform stations have side platforms that are located at different levels (usually due to context alignment or constraint). Its design considerations are similar to those of conventional side platform stations. A platform should not be used as a path to the other [13]. Lack of freedom in designing, low width of the concourse, illegibility of train directions on the platform, less interference with the city level, and consequently fewer restrictions are the features of this type of station [16]. "Bukit Bintang" MRT station is an example of this type [17].

4.2.4. Stub Terminal Stations (ST)

Stub Terminal Stations have central or lateral platforms (or a combination of both) in which routes are dead-end and allow passengers to access the platform dead-end. This platform uses the advantages and disadvantages of central or lateral platform stations depend on its configuration. This type has the advantage of adding high-capacity inputs or outputs from the bottom of the platform, making them suitable for large passenger flows, special events, and airport/seaport stations. "Chhatrapati Shivaji Terminus" is an example of this type of station [13].

4.2.5 Flow-Through Platforms (FT)

Flow-Through Platforms allow passengers to board and ascend trains from dedicated platforms, thus eliminating conflicting movements of the passengers. Flow-Through Platforms speed up the boarding and disembarking of passengers, and reduce train stopping time on the platform. Flow-Through Platforms are not usually used due to high cost and operational

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considerations. But they have a very large volume of passengers controlling feature [13]. Budapest Keleti railway station is an example of this station [18].

4.2.6 Bay Platforms (B)

Bay Platforms are the starting point or endpoint of the route and all passengers get on or off. Also in these types of stations, the train enters or leaves the station. These platforms are mostly used in Australia and the United Kingdom. “Carlisle” Station in London is an example of this type [19].

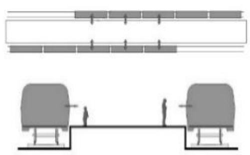
4.2.7 One Side platform (O)

The platform in this type of station can be designed according to the flow of passenger traffic and the amount of boarding and disembarking along with the entire environment. The fast connection between buses, taxis, and parking and easy access for the disabled is one of the advantages of this platform. The lack of correct recognition of the platform by the passenger, balance access between and security, interference movements, and long walks are the disadvantages of this type. “Rävlanda” Station is an example of such a station.

4.2.8 Mixed Platforms (M)

This type of station is, a quadruped-line combination of center and lateral platforms, designed for very large and voluminous stations. It’s most important advantage is the quick access between two center platforms for fast transferring. But the vague connection to the environment is one of its disadvantages. “Flemingsberg” Station is an example of this type [20].

Table 4: Geometric classification (Source: Authors)

Station code	Types of station geometry	Features		diagram (Plan and section)	Case study
		Functional benefits	Functional disadvantages		
I	Island	Readability of the route, more efficient use of space, less width of the platform, less number of elevators and escalators, rerouting of the train without changing level, high safety, easier installation of equipment, centralized facilities for disabled	Vertical alignment, limited elevator options, less wall space for signs and advertising, limited flexibility for future expansion Wider than side platform, larger escalators and elevators, wider rail tunnels		“Shahid Kolahdooz” in Tehran

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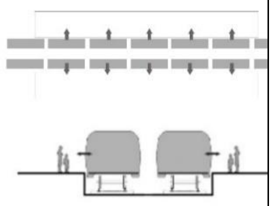
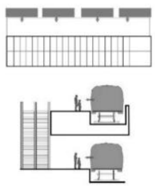
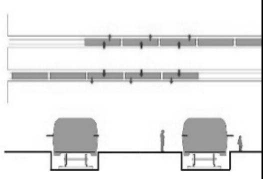
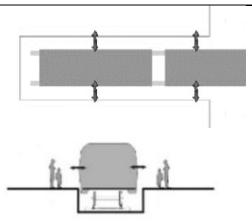
TS	Two Side	Different emergency exit, acceptance of a large number of passengers, better accommodation of passengers due to reduced queuing, more flexibility for future expansion, more space and easier access to the wall for signs andadvertising	Need of decision for the passenger before entering the platform, need of changing the level to change the direction of the train, less space efficiency, installation of equipment problems, wide width of stairs, large number of escalators, need of placing facilities for disabled on each platform, need for more staff		First phase stations of Shiraz metro line1
SL	Split-Level	Reduce passenger engagement in the queue, enough space on the wall for signs and advertisements, no need to decidebefore entering the station	Vertical movement, need for great depth of the station, number of stairs and escalators, need to place facilities for the disabled on each platform		“Bukit Bintang ” MRT station
ST	Stub Terminal	Convenient and flexible emergency exit, reception of a large number of passengers, exit at the end of the platform	Possibility of functional defects appropriate to the type of platform configuration		Chhatra pati Shivaji Termin us
FT	Flow-Through	Separation of conflicting passenger routes, facilitating the movement of passengers with luggage, high capacity for vertical movement	Operational complexities in implementation and high cost		Budape st Keleti railway station
B	Bay	High passenger security, need for less control by staff, dedicated to terminal stations	Not accepting a large number of passengers		Carlisle Station
O	One Side	Fast connection between bus, taxi, and parking, easy access for disabled	Lack of recognition of the platform by the passenger, creating a balance between		Rävland a

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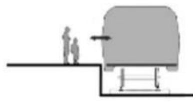
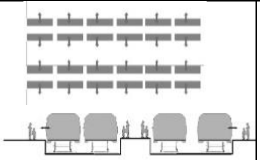
			access and security, creating traffic interference, long-distance		
M	Mixed	For very large stations, access between two island platforms for fast transfer	Unspecified connection to the environment		Fleming sberg

4.3 Urban Scale characteristics

The scale characteristics of metro stations are about the scale of the station in the city, the way of service, and the need for lateral spaces. This type includes city center, airport/seaport, town center, Regional Park and ride, neighborhood, employment center, Local Park and ride, and special events venue (Table 5).

4.3.1 City Center (CC)

City center stations serve as gateways for large numbers of passengers. Due to the large volume of passengers, bus, taxi and other means of transportation are needed. As this type is a goal station, there is no need for parking, however, parking lots of nearby buildings can be used if needed [21]. Also, these types of stations can be available as multi-purpose stations with different activities [22]. JR “Shinjuku” Station in Tokyo is an example of this type of station [3].

4.3.2 Airport/Seaport (S)

These stations are often "source" and "goal" stations and have an urban and metropolitan role. This type has varied audiences and includes travelers such as tourists, visitors, staff, and other local travelers. Moving walkways can be provided to facilitate the movement of passengers, especially travelers with luggage [8] [21]. These types of stations are accessible by bus, temporary parking, bicycle, and pedestrian. It is the best option to access the bicycle station [22]. These types of stations can be divided into two categories: substation stations and the city center [5]. Urban stations are in the middle of the network rail, and most trains end their journey [23]. Some stations of this kind are built next to the city's main airports to serve incoming and outgoing passengers [5].

Since the travel destinations of passengers are very different in terminals, most passengers need some special services. Services to be considered at terminals: toilets, temporary rest area (couch, chairs for the elderly, women with children), public telephones, and other communication services such as the Internet and also first aid and law enforcement services [8][5]. “Shahid Dastgheib” station in Shiraz is an example of this type [24].

4.3.3 Town Center (T)

These stations are located in the city or at the edge of the main context of the city, as urban nodes. These stations are both source and goal and include a diverse group of travelers with

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different goals and activities. As these stations are very crowded and involve huge walking groups, many facilities are needed. These facilities include restaurants, toilets, shopping malls, and public transportation services such as buses, motorbikes, bicycles, and taxis. Parking can be limited in the surrounding streets or in the back buildings that are accessible, with complete security, can be designed [8] [5] [21] [22] [23]. “Hague Souterrain's station” in Rotterdam is an example of this type [3].

4.3.4 Regional Park and Ride (R)

These stations are located near major roads with close connections to highways. These stations are at the node of the connection point of the city with the suburbs [8]. Temporary parking lots and bus stops should be located close to the station entrance. Passenger access may also be by personal vehicle. Therefore, it needs large parking lots. Passengers can park their car in the parking lot and take the subway to work [5]. As vehicles and buses deviate from the main road, separate one-way roads help minimize traffic congestion in remote areas [6]. “Ghods” metro station In Isfahan is an example of this type [25].

4.3.5 Neighborhood (N)

The term neighborhood refers to the smallest planning unit within the city [26]. These types of stations are located outside the main city, and passengers of these stations are locals, so the station functions as a sourcepoint. The station connects to a square or street in the neighborhood [8]. Due to the smallnumber of passengers, it needs retail, newspaper stands, coffeeshop, ice cream, injection departments, and public offices. It must be accessible by foot, bus or bicycle. Parking is shared at various times on a proportionate scale on the ground or shared with multi-purpose buildings of a government or special institution such as a mosque [5][21]. “Golshahr” station in Karaj is an example of this type [27].

4.3.6 Employment Center (E)

These stations are intended for employment centers, such as office buildings, hospital complexes, universities, large multifunctional cultural centers, and shopping malls. Passengers can reach their destinations on foot, and if further, they can reach their destinations by bus. A plaza can be included in front of the station and surrounding areas. Due to the high volume of traffic in these stations, which are peak hours during the week and working hours, morning, noon, and evening, the plaza can accommodate more people in a short period. Since this station is mainly a goal station, no private parking is required. Parking lots of existing buildings can be used, If needed [8] [21]. “Jing’an Temple” Station in Shanghai is an example of this type [3].

4.3.7 Local Park and Ride (L)

These stations have a moderate volume of traffic. Pedestrians should be designed to move from parking lots or buildings to the station entrance while maintaining public safety. Temporary parking lots and bus stations should be located near the entrance to the station on the ground. Also in remote areas, suitable retaining plants can be used to separate the areas of vehicles,

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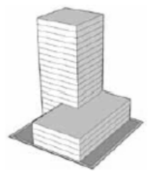
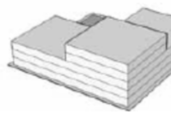
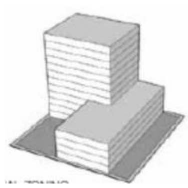
bicycles, and pedestrians [21]. “Shahed” metro station in Shiraz, Iran is an example of this type [28].

4.3.8 Special Events Venue (V)

These stations must be explicitly designed to cover that particular location. The station and the surrounding areas must simultaneously manage large populations for a short period. Overpasses can be used to connect people to the stadium or the building of the stations. If that special event building is single-use, there is no need for parking lots. If possible, an overpass from the parking lot to the station, stadium, or venue can be taken [21]. “Azadi Stadium” metro station in Tehran is an example of this type [29].

Table 5: Urban Scale Classification (Source: Authors)

Station code	Types of station scales	Features		diagram (Sample of the surrounding neighborhood)	Case study
		Neighborhood	Station requirements		
CC	City Center	ratio of commercial area less than 10, number of residential units more than 25 units per hectare, one parking unit less than 90 square meters	context area less than one hectare, access to all transportation services without the need for private parking		JR Shinjuku
S	Airport/Seaport	It does not need any neighbors Until combined with other types of stations	context area less than one hectare, access to local fast transport services without the need for private parking	-	Ayatollah Shahid Dastgheib station in Shiraz
T	Town Center	Ratio of commercial area less than 2.5, number of residential units more than 15 units per hectare, 1.5 parking units less than 90 square meters	context area between one to two hectares, access to fast transportation services and the need for private parking with a capacity of 50 to 200 units		Hague Souterrain
R	Regional Park and Ride	The ratio of the commercial area is less than 6, number of residential units more than 25 units per hectare, 1.5 parking units less than 90 square meters	context area of more than 5 hectares, access to local transportation services, and the need for private parking with a capacity of 600 to 2000 units		Isfahan Ghods
N	Neighborhood	No commercial units, no more than 8 residential units per hectare, no parking	context area between 1-2-2 hectares, access to local transportation services, and the need for private parking		Golshahr station in Karaj

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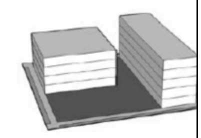
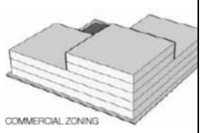
			with a capacity of 50 to 100 devices		
E	Employment Center	Commercial area ratio less than 2.5, number of residential units more than 25 units per hectare, 2.25 parking units less than 90 square meters	context area less than one hectare, access to local transportation services without the need for private parking		Jing'an Temple
L	Local Park and Ride	Ratio of commercial area less than 2.5, number of residential units more than 15 units per hectare, 2.25 parking units less than 90 square meters	context area between two to six hectares, access to local transportation services, and the need for private parking with a capacity of 200 to 600 units		Shahed Shiraz
V	Special Events Venue	It does not need any neighbors until it is combined with other types of stations	No need for a specific area, access to fast transportation services without the need for private parking	-	Tehran Azadi Stadium

4.4 Functional Features

Functional features of metro stations are how the station operates on the lines that are located, including passing, crossing, and exchanging stations (Table 6).

4.4.1 Passing Stations (P)

Only one line passes through these types of stations. The number of such stations is a very large amount. The "Stadion" of Sweden [30] and "Shahid Doran" Shiraz [31] are examples of this type.

4.4.2 Crossing Stations (C)

Stations where two or more lines intersect. In Iran, intersection stations connect two or more lines in the center of a station and the lines are accessible to each other through the level of the Concourse. In this type of station, maps of all stations on other lines must be specified [8] [23]. "Valiasr Square" Station and "Theater" Station in Tehran [32] and Berlin Central Station [3] are examples of intersection stations.

4.4.3 Exchange Stations (E)

Stations where two or more stations in different lines are adjacent to each other[23] [8].Exchange Stations are located at the intersection of railways, which in addition to the volume of passengers of origin-destination, also serve a large number of transfer passengers. It is important to minimize delays at these stations, as lane changes and delays due to the use of transmission devices greatly increase passengers' perceived travel time. Besides, at such stations, each transfer passenger uses the station facilities twice. This means that supply must

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be designed to double demand due to the disembarkation and boarding of transit passengers. In this type of station, design considerations should be considered, including the use of moving walkways for distances of more than 150 meters. Transmission conditions between lanes for low-capacity passengers and construction of dedicated corridors must be considered [33]. In the future planning of Tehran metro lines, line 8 will be exchanged with line 3 at "Shariati" and "Khajeh Abdullah Ansari" stations [34].

Table 6: Functional Classification (Source: Authors)

Station code	Types of station functions	Property	diagram (Location)	case
P	Passing	station located on a line		Stadion of Sweden and Shahid Doran Shiraz
C	Crossing	station located at the intersection of two or more lines		Tehran Theater and Berlin Central Station
E	Exchanging	intermediate station in a line connected to an intermediate station in another line		Shariati and Khajeh Abdullah Ansari stations

4.5 Adjacent Features

Although the function of a metro station building is primarily to transport, in the world's most populous cities including Tokyo, Seoul, Beijing, Helsinki, etc. are planning to enhance capabilities and availability, and design multipurpose station centers, so construction of these complexes has important strategies for their urban development plan [35]. The benefits of the construction of such a complex include economic interests, social interests, the interests of urban development, and transportation and environmental benefits [36]. Since today metro stations are beyond a normal station in services and also have main spaces for the Concourse and the platform, they have a lot of lateral spaces. Commercial spaces are one of the uses that can help in the future with the economy of the station and reimburse costs. Besides, it can provide more lively multi-function spaces for people. Adjacent features of metro stations are the construction of the metro as a station complex or its proximity to commercial-administrative complexes, which in the design of metro stations includes No Connection to any user, adjacent Complexes, or combined.

4.5.1 No Connection to any user (NC)

In some stations, there is no use other than Concourse.

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4.5.2 Station complexes

4.5.2.1 Adjacent Complexes (AC)

Urban railway organizations can purchase station area properties when defining lines and stations in the urban space to define station complexes where metro accesses are located or are transported independently from the basement to the stations. In the basement of the complex, car parking is designed for the use of passengers, on the middle floors, booths, and commercial halls, and on the upper floors, sports, cultural and office halls can be considered. The "Orestad" metro station in Denmark [37] and the "city of Aftab" in Tehran [38] are examples of this type.

4.5.2.2 Subterraneous Complexes (SC)

In the methods for constructing tunnels of subway lines at the level below the street, instead of filling the level from the tunnel to the street level, commercial floors can be considered by constructing concrete roofs and booths and commercial halls can be defined in these spaces. Also, a commercial complex can be defined next to the accesses in the Concourses that it increases the value of Concourses when entering and leaving. "Montreal" station [37], "Zandieh" and "Vakil" Shiraz metro stations [39] are of this type.

4.6. Internal communication features

The characteristics of the internal communication of metro stations are how the two main components of the station, ie the Concourse and the platform, communicate with each other. The subcategories of this part include Concourse above the platform, Concourse under the platform, Concourse next to both sides of the platform, Platform next to both sides of the Concourse and separate Concourse (Table 7).

4.6.1 Concourse above the Platform (TAP)

These types of stations can be run in middle-deep or shallow depths or on level roads. The easiest model, using uncontrolled space as an underpass of urban thoroughfares at shallow depths, reducing station interference with the network of urban facilities, less acquisition than other categories, and combining the entrance with other urban uses are the advantages of this type of stations. Low facilities for arranging space and low flexibility due to the geometry of the Concourse from the platform, limited entrance location, low legibility due to successive changes of direction, lack of horizontal expansion, and lack of integration with urban space, are the disadvantages of this type. "North Greenwich" Station [37] and Shiraz "Forsate Shirazi" Station [38] are examples of this type.

4.6.2 Concourse Under the platform (TUP)

In this type of station, the train is at or above ground level. Less dependence of the Concourse on the geometry and form of the platform, the ability of the Concourse to expand in different directions, free entrances, easy access to both platforms, greater readability of the space, uncontrolled section as an underpass, reduction of ventilation, and acquisition costs, limitations traffic less than other modes, integration with other urban activities around, are the advantages

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of this type. Dealing with urban facilities due to shallow depth is the most important drawback of this type. Expo station in Singapore is a kind of this type [37].

4.6.3 Concourse Next to both sides of the Platform (TNP)

This type of station would be constructed in a shallow or level path. The access between the platform and the Concourse is provided by the rail or below. In this type of station, the Concourse is located on both sides and one side of the platform but usually is on both sides. If the connection between the Concourse and the platform is under the rails, access to the opposite platform is difficult and passengers make the transfer from the city. If the connection between the Concourse and the platform is by rail, access is easier and the communication corridor is more practical. The high flexibility of the Concourse and perfectly coordinated with the context, free entrance design, integration with urban uses, legibility of the route, visual communication between indoor spaces and surrounding passages, and the possibility of providing natural light are some of the advantages of this type. The interference with urban facilities, making many restrictions in traffic due to the shallow depth, breadth of the plan, and the ability to develop along the passages are of the disadvantages of this type of station [16][40]. “Roodebeek” station in Brussels [16] and “Ehsan” in Shiraz [39] are examples of this type.

4.6.4 Platform Next to both sides of the Concourse (PNT)

In this type of station, the Concourse is located in the middle of the platforms, and if the platform is an island, the distance between the rails should be equal to the amount of the Concourse. Determining the location of the entrances before determining the location of the station must be considered. Ease of access from the platform to the Concourse, direct connection of elevators to the platform, and legibility of the route are the advantages of this type. Interference with urban facilities, blocking car and pedestrian traffic in the surrounding passages due to the shallow depth, and the ability to develop the station only at the entrances are the disadvantages of this type of station. “Abando Bilbao” station is an example of this type [16].

4.6.5 Separate Concourse (STH)

Due to the separation of the Concourse from the platform, the prerequisite for selecting this template is the existence of suitable facilities on the site to locate the Concourse. Reducing restrictions during the construction of the station in the surrounding passages, future development capability, freedom in designing the architecture of the Concourse and combining it with other urban uses, and increasing soil slag on the platform, are the advantages of this type. The need for land with suitable dimensions to locate the Concourse, reduce the efficiency of the surrounding space, access to the station on one side of the street, difficult access to the opposite platform, and successive change of directions are the disadvantages of this type of station. Flon Lausanne Station is an example of this type [16].

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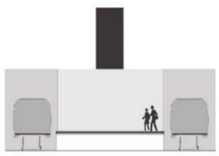
Table 7: Classification of Internal Communication (Source: Authors)

Station code	Types of internal communication of the station	Features		diagram (Section)	case
		Functional advantages	Functional disadvantages		
TAP	The concourse above the platform	Easy pattern, uncontrolled space as an urban gateway, reduced interference with urban facilities, less acquisition	Low flexibility and readability, lack of horizontal expansion, lack of integration with urban space		"North Greenwich" and "Forsate Shirazi" Station
TUP	Concourse Under the platform	Less dependence of the hall geometry on the platform, the ability to expand the hall, fewer traffic restrictions, integration with other urban activities	It has no functional defects		Singapore Expo
TNP	Concourse next to both sides of the platform	The high flexibility of the hall, free entrance design, legibility of the visual communication path between the interior spaces, the possibility of providing natural light	Interference with the network of urban facilities, creating high restrictions on traffic		"Roodebeek" stations in Brussels and "Ehsan" Shiraz
PNT	Platform next to both sides of the Concourse	Ease of access from the platform to the Concourse, direct connection of elevators to the platform, legibility of the route	Interference with urban facilities, the ability to develop the station only at the entrances		Abando Bilbao
STH	Separate Concourse	Reducing restrictions during the construction of the station, future development capability, freedom in designing the architecture of the Concourse, integrating it with other urban uses	Existence of suitable site facilities, land with suitable dimensions, reducing the efficiency of the surrounding space		Flon Lausanne

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5. DISCUSSION

As discussed, categorizing metro stations is important to align the capabilities of the context and the station to turn them into a place beyond a simple platform for boarding and disembarking. According to studies on the type of metro stations, six general categories of alignment level, geometry, urban scale, function, adjacent, and internal communication were identified. In the alignment level classification, three subsets of underground, aboveground, and elevated were identified and the factors influencing the selection of this type of station were investigated.

Also, underground stations were classified into deep, semi-deep, and shallow stations in terms of depth and flat and arched in terms of roof type according to the type of drilling. Aboveground stations were identified in terms of the type of one-way, two-way, and two-way canopies separately. In the geometry classification of metro stations, the types of island platforms, two side platforms, split-level platform, stub terminal platform, flow-through platforms, bay platforms, one side platform, and mixed platforms were mentioned and the advantages and disadvantages of each were examined.

In the urban scale classification of metro stations, city center, airport/seaport, town center, Regional Park and ride, neighborhood, employment center, Local Park and ride, and special events venue were mentioned. According to the type of scale in the city, side spaces and specifications of commercial, residential, and parking uses required around the station were identified.

From a functional point of view, passing stations, crossing stations, and exchange stations, and a proximity point of view, if there are commercial spaces in the basement or adjacent to them, they were classified according to the environmental conditions of the context. In the category of internal communication, according to the context and location of the station in the city, different categories were considered for locating the Concourse and the platform, which are the main spaces of metro stations, relative to each other.

For homogeneity in classifying the types of stations, a revision in categories has been done (Fig. 4). So in alignment, function and adjacent category three types have been shown. In geometry, urban scale and internal communication category the classify has been reclaimed. In geometry type, the categories have been displayed in three types based on the manner of entering the train in the platform (Fig. 1). The other types can be regarded as one of four types based on the manner of entering the train from the platform.

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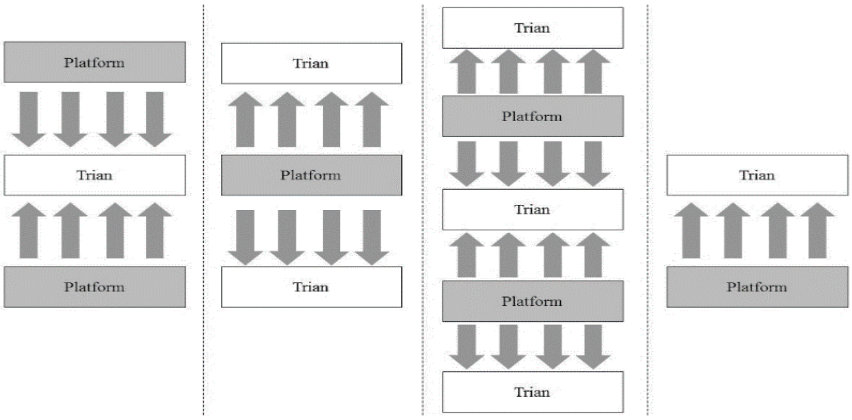
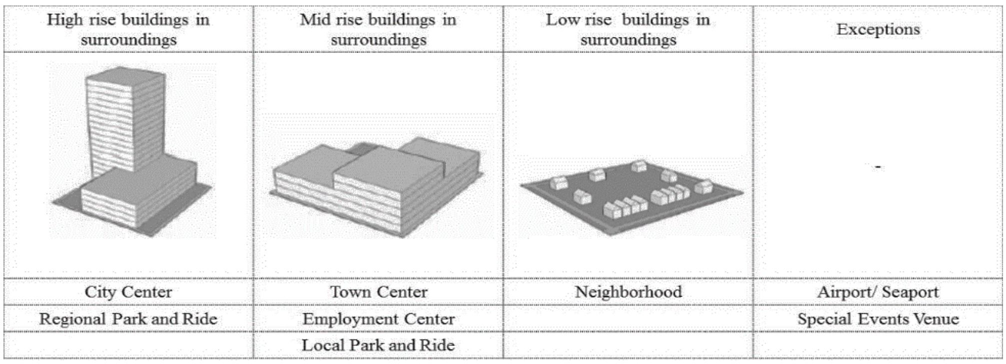


(a) (b) (c) (d)

Fig 1: Reclassifying geometrical metro stations based on the manner of entering the train

a) Enter from two sides to two trains from two platforms (Two-side and Split level) b) Enter from one side to two trains from one platform (Island-Terminal-Bay) c) Enter from one side-two sides to three or more trains from two platforms or more (Mixed and Flow-through) d) Enter from one side to one train from one platform (one side) (This type can be used for Cross-section stations too)

In the Urban-Scale type, the categories can be displayed in four types, based on scale differences in the surroundings' view of the service station (Fig 2.). The other types can be regarded as one of these four types based on the scale of the service station.



(a) (b) (c) (d)

Fig 2: Reclassifying Urban-Scale metro stations based on differences in scale from surroundings view of service station: a) High-rise buildings in surroundings (City Center and Regional Park and Ride) b) Mid-rise buildings in surroundings (Town Center- Employment Center- Local Park and Ride) c) Low-rise buildings in surroundings (Neighborhood) d) Exception surroundings (Airport/ Seaport and Special Events Venue)

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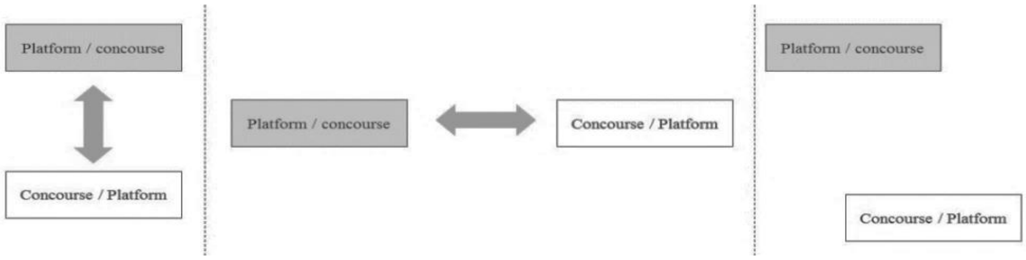
In the Internal communication type, the categories can be displayed in three types, based on the state of communication between concourse and platform (Fig 3.). The other types can be regarded as one of these three types based on this relation.



(a) (b) (c)

Fig 3: Reclassifying Intercommunication metro stations based on the state of communication between concourse and platform: a) Vertical Communication (Concourse above the Platform and Concourse Under the platform) b) Horizontal Communication (Concourse Next to both sides of the Platform and Platform Next to both sides of the Concourse) c) Separate Concourse and Platform

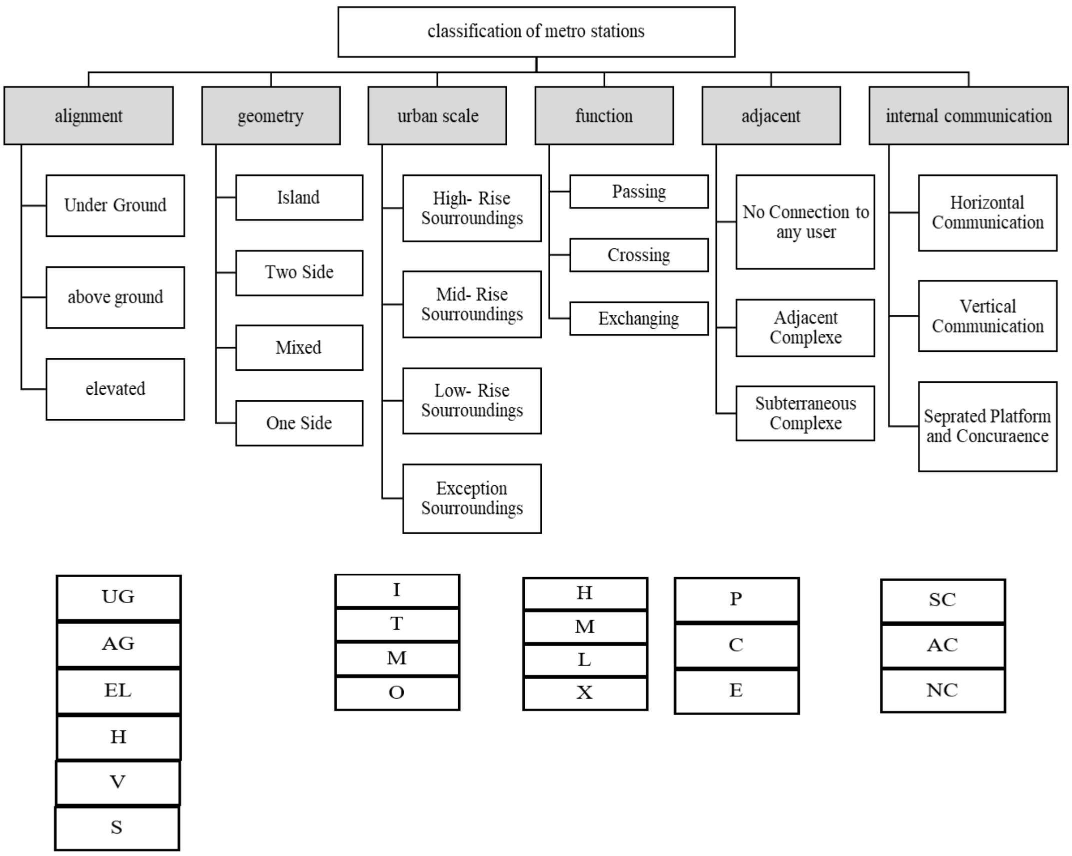


Fig 4: Concepts of classification of a metro station and the new codes

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6. AN ILLUSTRATIVE EXAMPLE

Shiraz is the sixth biggest city in Iran, the capital of Fars Province. It has a population of 1.5 million in 2016. According to an official survey, the shares of the different modes of travel in this city are as follows: private cars, taxis, public buses, and its urban railway network which is in continuous evolution. [41].

Line1 of Shiraz metro with a length of 24.5kmconnects the east-west route of Shiraz from "Ehsan" to "Shahid Dastgheib" (Fig. 5 & 6). It is the longest urban train line in the country after Tehran, concluding 20 stations. All stations have been ordered in a matrix based on the classification described (Table 8). The code of each station has been defined by a field survey and post-production evaluations (Table 9).

Fig 5: Shiraz metro stations in Line 1

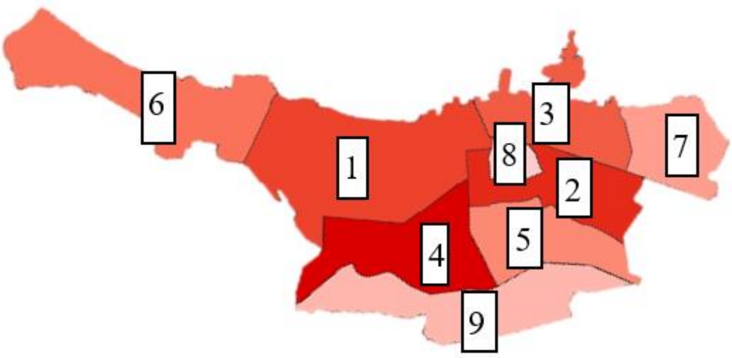

Fig 6: Map of population distribution of Shiraz city by municipal area (A large part of Line 1 is located in a densely populated are)

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6.1 Restoration

Alignment: By analyzing Table 8, all the stations in line 1 shiraz metro are UG stations from the Alignment view. From "Ghasrodasht" station to "Ehsan", stations are the semi-deep type with one floor, which most of them have horizontal relation between the platform and the concourse. The other stations are deep with two floors and vertical relation between the platform and the concourse except for "Vakil", "Zand", and "Emam Hossein" stations which have three floors. So it can result in a relationship between alignment and internal communication categories.

Geometry: The geometry platform of stations in the first phase is T and in the 2nd phase is I. Platform of the "Emam Hossein" station which is crossed with line 2 is M. It can be seen there is a relationship between geometry and function. (P types in function category are a kind of I, T or O in geometry, and C types in function are M in geometry)

Urban Scale: The types of stations in urban scale view are different. The first station "Ehsan" and the last station "Shahid Dastgheib" are X type while in their proximity there are no bold other types of public transportation for commuters. So it is suggested that the designers consider some bus, taxi, bicycle and other types of public transportations and other services such as toilets, temporary rest area internet and also first aid and law enforcement services. The number of entrances of "Shahid Dastgheib" station which is in the airport surroundings is four but it doesn't have any straight connection to the airport. It is suggested that some walkways or other kinds of services used. Also, because it is the first thing that a traveler sees from the city, the design can be improved. There are three entrances to the "Ehsan" station which seems enough for a terminal station.

"Zanidiye", "Emam Hossein", and "Namazi" are in the city center with type H. "Mirzaye Shirazi" station is surrounded by high-rises and 3rdline will be extended from this station. "Zandiyeh" and "Emam Hossein" stations have six entrances while "Namazi" and "Mirzaye Shirazi" have four. The number of these entrances is designed based on the neighborhood and the entrances' location. "Namazi" station is a kind of station that needs a plaza nearby.

"Doran", "Ghadir", "Fazilat", "Kaveh", "Valiasr", "Vakil", "Avini", "Motahari", "Ghasrodasht" and "Sahriati" stations are in Mid-rise neighborhood with type M. Due to the need for some facilities such as restaurants, toilets, shopping malls, public transportations services, and parking lots in type M, these stations need such facilities. "Vakil" which has been opened recently has some but others have better to be considered. "Doran", "Kaveh", "Avini", "Ghasrodasht" and "Sahriati" have three entrances and the others have four. The number of these entrances is designed based on the neighborhood and the entrances' location. A temporary parking lot can be designed near one of these entrances.

"Forsati", "Janbazan" and "Shahed" stations are L type. Some facilities such as parking lots and bus stations need to be considered. Just the "Shahed" station has temporary parking around and the others should be designed. "Forsat" and "Shahed" stations have three entrances and "Janabzan" and "Razi" have four. The number of these entrances is designed based on the neighborhood and the entrances' location. It can be seen there is a relationship between urban

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scale and adjacent. Stations with H and M type in urban scale category need any kind of commercial use in or around the station because of the high population servers.

Function: All stations except "Emam Hossein" are with type P in function view while "Emam Hossein" is type C. It seems some stations that are near to other lines will be considered as E type in future studies.

Adjacent: In the adjacent view, there are just two stations with AC type and six stations SC and the other are NC. Shopping centers are an integral part of the urban system and various parameters have been effective in creating such a transformation, perhaps the most important of which is the development of cities and the entry of modernization in their body. Certainly, the impact of the urban transportation system cannot be denied, although the first role of these centers, which is imagined in the first place, is the economic role, but it takes place in shopping centers of various cultural and social exchanges. Given the expansion of public transportation systems such as the metro in Shiraz and awareness of the effects of the metro on the quality of the surrounding environment, intelligent management of metro stations can be considered an important opportunity to move stagnant economies to vibrant ones with dynamic economies. It is recommended for the stations with NC type, especially in "Eamam Hossein" station, designing some commercial places (whether near or in the station).

Internal Communication: Three stations ("Mirzaye Shirazi", "Shariati", and "Ehsan") are H (with TNP type in details). The other stations except "Vakil" are V type (with TAP type in details). "Vakil" station has separated concurrence and platform wich its type is S. The Hs are shallow and Vs are semi-deep. It means the original soil of Shiraz generally has surface waters at the semi-depth level (Fig.7).

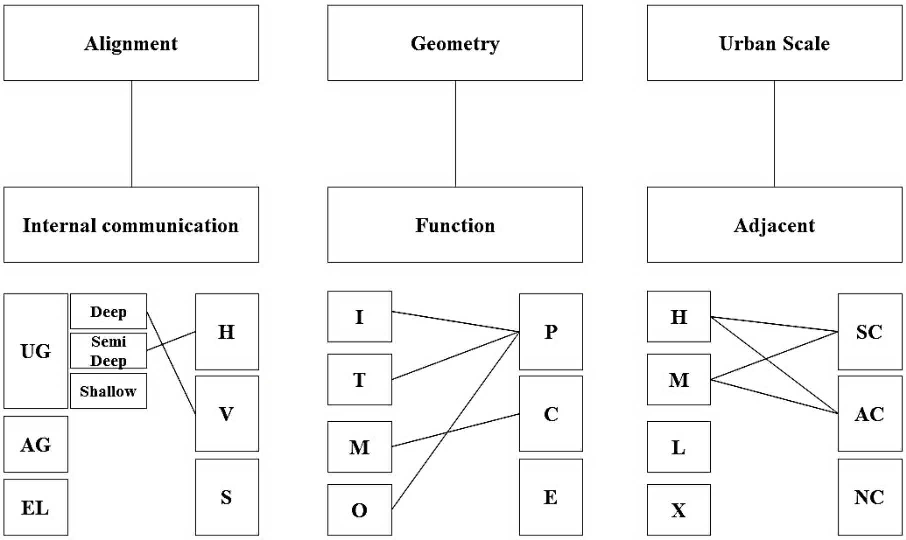

Fig 7: A conceptual idea of a relationship between categories for designing metro station in Shiraz, Iran

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7. CONCLUSION

Metro stations are considered as strategic points of densely populated cities for intra-city transportation. In addition to designing lines and crossing points of metro lines, it is necessary to determine the exact location of stations in the next stage of urban planning. For this purpose, it is necessary to precisely control urban structures at the crossing point of metro lines.

Determining the location of the metro station and the connection with the urban context, access, available services, geometric shape, enter and exit to the wagons, the scale of the station according to its location in the urban context, the performance of the station in line/lines are important factors that should be considered in the design.

In recent years, metro stations have become not only platforms for passengers to board and disembark, but also places to increase social interaction in line with the goals of sustainable development goals, as well as networking and integrating the entire city under, at, and above the ground. In the literature review, preliminary and partial categories were observed, but the general classification of stations along with the introduction of architectural features, their advantages and disadvantages, and opting for them were not observed.

Therefore, in this article, to design metro stations in the initial phases and with a comprehensive and integrated view of the entire urban context, six general categories were introduced while considering the crossing points and responding to the needs of passengers. Designers can adopt a variety of approaches in six categories, depending on the type of each station, and consider the necessary features in the design according to the type of features used in terms of Alignment, geometry, scale, performance, adjacent and internal communication. Therefore, there is a need for a specific category to select the type of station, and optimal design in terms of efficiency and performance of the station is essential.

According to the organization of studies, necessary studies, tables, and available content, designers can study all the features and technical practical specifications, how to access the train and passenger route, lateral spaces, and future potentials of the station before starting the design and with a more logical process, design suitable metro stations according to the needs of the context. Also, due to the great variety of categories, each category can be set as code, and before designing the desired station for technical and managerial approaches, identified all the factors involved in the design.

Also, in Iran with the increasing need for large-scale transportation and the growing importance of Transit-Oriented Developments, the design of rail transportation stations is one of the research topics for Iranian engineers and architects. Then, an analysis of the architectural design metro station for the validity of classification and comprehensive consideration in Shiraz metro line 1, was done.

The confusion matrix is used to provide an assessment of the correspondence between the classifications for 20 metro stations in line 1, Shiraz, Iran. Moreover, the ground data are an accurate representation of the ground conditions or the necessary information on the sampling design used in the iracquisition provided. Although there have been many recent advances, the

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current status of accuracy assessment indicates that numerous problems remain to be solved. Thus, the subject has matured considerably, there is scope for significant further development. Many of these issues have been raised in the literature before and have been simply revisited here concerning recent examples, which act to emphasize the need for the community to critically evaluate its procedures and change as appropriate to progress.

This is particularly important concerning the mapping of very large areas and monitoring of change, where designing a metro station remains a challenging task with considerable scope for further development.

Data Availability

All data, models, and code generated or used during the study appear in the submitted article.

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Table 8: Matrix of 20 metro stations throughout line 1, Shiraz, Iran

Stations		categories																				Station Code
		Alignment			Geometry				Urban scale				Function			Adjacent			Internal communication			
		UG	AG	EL	I	T	O	M	H	M	L	X	P	C	E	SC	AC	NC	V	H	S	UG-I-X-P-NC-V
2nd phase construction	Shahid Dastgheib	*			*							*	*					*	*			UG-I-M-P-NC-V
	Doran	*			*					*			*					*	*			UG-I-L-P-NC-V
	Forsat Shirazi	*			*						*		*					*	*			UG-I-L-P-NC-V
	Janbazan	*			*						*		*					*	*			UG-I-M-P-NC-V
	Ghadir	*			*					*			*					*	*			UG-I-L-P-AC-V
	Razi	*			*						*		*				*		*			UG-I-M-P-NC-V
	Fazilat	*			*					*			*					*	*			UG-I-M-P-NC-V
	Kaveh	*			*					*			*					*	*			UG-I-M-P-NC-V
	Valiasr	*			*					*			*					*	*			UG-I-M-P-SC-S
	Vakil	*			*					*			*			*					*	UG-I-H-P-SC-V
	Zandiyeh	*			*				*				*			*			*			UG-M-H-C-SC-V
Cross with line 2	Emam Hossein	*						*	*					*				*	*			UG-T-H-P-NC-V
1st phase construction	Namazi	*				*			*				*				*		*			UG-T-M-P-NC-V
	Avini	*				*				*			*					*	*			UG-T-M-P-NC-V
	Motahari	*				*				*			*					*	*			UG-T-M-P-NV-V
	Ghasrodaht	*				*				*			*					*	*			UG-T-L-P-NC-H
	Shahed	*				*					*		*					*	*			UG-T-H-P-AC-H
	Mirzaye Shirazi	*				*			*				*				*			*		UG-T-M-P-AC-H
	Shariati	*				*				*			*				*			*		UG-T-X-P-AC-H
	Ehsan	*				*						*	*				*			*		