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RESEARCH PAPER

Analysing Complete Street Design Principles Using Space Syntax Methodology in a Case of Haft-e-Tir Square, Tehran

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Abstract

Research on urban fabric has long been a focus of interest for researchers and planners. In response to the automobile-centric design of cities, approaches such as Complete Streets have emerged to create accessible, people-centric environments by integrating various transportation modes. The study is to understand how complete street design strategies influence the connectivity and integration of the urban fabric, focusing on Haft-e-Tir Square in Tehran as a case study. Employing space syntax methodology, the current layout and a design proposal based on Complete Street strategies for the square had analysed to reveal the impact of this planning and design principle on the city's urban fabric. The result uncovers how Complete Street hold promise in improving urban functionality and elevating the life quality. The design proposal's interventions proved that by prioritizing pedestrians, cyclists, motorists, and transit riders, the level of safety, walkability, liveability, and environmental sustainability of the area can improve. Moreover, the findings showed a considerable reduction in the pedestrian and traffic congestion, resulting in supports for local businesses and improved urban functionalities. By contributing to the ongoing discourse on Complete Streets and its impact on shaping urban environments, this research is paving the way for future studies in this area.

Keywords Complete street · Urban fabric · Connection analysis · Integration analysis · Pedestrian and traffic flow

Introduction

The term 'urban fabric' known as the physical texture of urban areas which includes the streetscapes, buildings, soft and hard landscaping, signage, lighting, roads and other infrastructure. As Levy (1999) describes it, urban fabric consisting of built structures, streets, constructed spaces, and open areas, defines the essence of cities. It includes historical and geographical forces, resulting in a complex interplay of plot, street, constructed space, and open space and profoundly influencing their identity and functionality (Levy 1999). Beyond physical landscapes, it embodies socio-cultural exchanges and historical legacies that shape urban character. This character is constantly changing due to various factors. In the modern urban fabric, streets have emerged as pivotal hubs of urban character's evolution and transformed into transportation infrastructure, profoundly influencing the identity and functionality of cities. Therefore, the dynamics between cities and automobiles has undergone multiple changes, influenced by various urban planning paradigms. Economic innovations known to have a notable impact on creating different transportation eras, such as pedestrian-oriented, transit-centric, and automobile-centric era, each impacting city expansion while these fabrics persist and evolve concurrently.

The increase in the usage of automobile and the widespread expansion of street networks in the early twentieth century (1920s and 1930s) caused fundamental changes in the urban landscape. As a result, traffic congestion and various pollutions had become rising concern for cities from the 1950s to the 1970s, let to a massive shift in urban planning strategies in favour of public transportation. Therefore, the idea of leaving cars at the outskirts of cities and walking the final 50 to 150 m home started to trendies in the late twentieth century and continued to be popular into the twenty-first century (Gehl 2011). This shift was resulted from transportation-dependent lifestyles, each embodying distinct spatial relationships and land use patterns.

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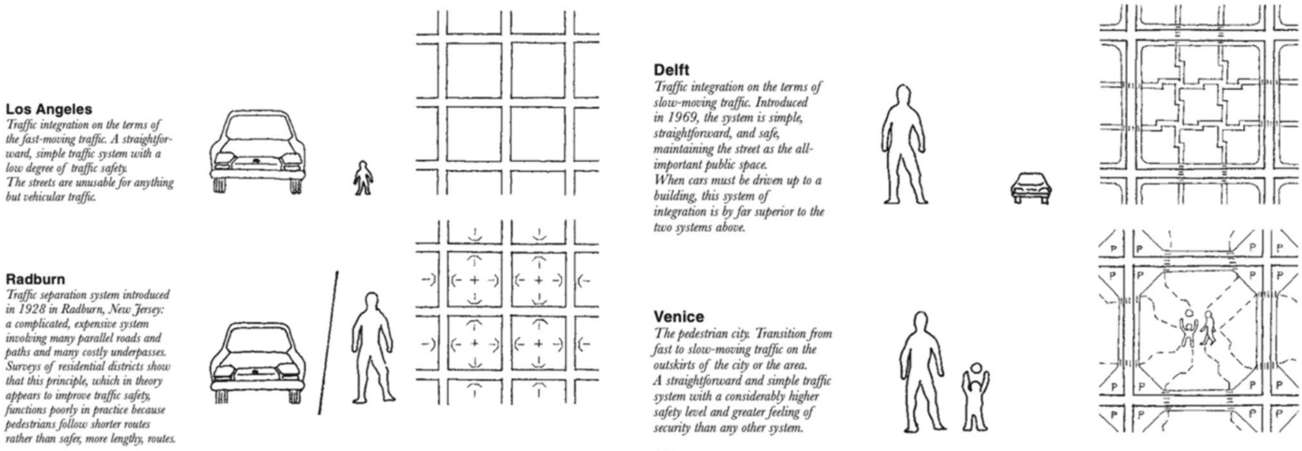

Fig. 1 Four Traffic Planning Principles showing the interplay between human and cars (Gehl 2011, 110)

In recent years, urban planning has begun to focus on fostering mixed-use developments, promoting transit-oriented designs (TOD), and prioritizing pedestrian and cycling infrastructure to address traffic congestion, reduce air pollution, and the promotion of healthier and more sustainable modes of transportation (Newman et al. 2015). This period saw the emergence of concepts like the Dutch "Woonerf", "Living Streets," "Inclusive Streets," "Streets for Everyone," and various approaches that emphasize shared street spaces and aim to create more equitable and accessible public spaces. These concepts prioritize the safety and convenience of all users, not just motorists, advocating for the inclusion of pedestrians, cyclists, and public transit in street design (Fig. 1).

The concept of "Complete Streets (CS)" arises within this framework as a pivotal facet, embodying an inclusive urban design approach that integrates diverse transportation modes, fostering accessible, people-centric environments. While CS may not directly incorporate traffic integration theories, its principles reflect a wider approach to urban design and transportation planning that emphasizes the usage of various modes of transportation and the creation of inclusive and accessible streetscapes.

Looking ahead to 2050, with a projected global population of 9.7 billion people, 68% of whom will reside in urban areas, the need for thoughtful development of urban environments becomes increasingly pressing (Pilkington 2020). The increasing urbanization underscores the importance of designing streets that can accommodate the growing population's diverse needs. Therefore, with the glamps at the past experiences, this study investigates the impact of such policies, specifically Complete Street (CS), on the urban fabric within a metropolitan setting. The research seeks to comprehend the influence of adhering to CS policies on the characteristics and functionalities of urban open spaces, particularly urban squares. By exploring how CS principles enhance urban areas, this paper aims to highlight the potential of CS in shaping cities that are not merely utilitarian but also aesthetically appealing and engaging for all residents. Employing spatial analysis on a design proposal based on CS strategies, the study intends to unravel the interactions between CS design principles and the urban fabric, exploring their capacity to reshape urban spaces into vibrant, liveable, and sustainable environments.

The investigation of the present paper primarily centres on Haft-e Tir square, a dynamic and bustling urban square in the heart of Tehran, that has undergone multiple transformations to adapt to the evolving needs of its citizens. Haft-e-Tir has faced significant challenges integrating pedestrians, vehicles, and public transport, with the subway stations extending population into the street and causing additional congestion. As a bustling commercial area for decades, it provides a rich context for exploring the impact of CS design principles on urban form.

Through this case study, the research examines how CS policies impact integration, connectivity, choice, entropy and communal engagement within urban settings, with a specific focus on Hafte Tir Square. It seeks to bridge the existing gap by meticulously analysing how CS principles shape and change the urban fabric. Space syntax has chosen for the analysis section because this method is a useful tool for comparing 'before' and 'after' conditions of spatial changes that result from restructuring (Yamu et al. 2021). The predictive capacity of space syntax analysis renders it an attractive methodology for urban planning and design. It contributes to an evaluation of spatial effects on locations of economic activity and the degree of vitality of urban centers (Hillier 2002). This approach emphasizes the necessity of adopting a comprehensive urban design perspective that integrates both

CS principles and space syntax analysis, aligning with the advocacy of prior scholars such as (Hillier and Iida 2005; Kim, et al. 2019). Quantifying street space redistribution is also essential to support functions beyond traffic. Streets shall viewed not just as efficient transit routes to move from A to B quickly, but as quality spaces that enhance the area between A and B (Furchtlehner et al. 2022).

The novelty and significance of this study lie in its innovative application of CS policies through space syntax methodology, specifically tailored to the unique context of Haft-e-Tir Square in Tehran. By combining empirical analysis with cultural and topographical considerations unique to Tehran, this research offers a fresh perspective on enhancing urban connectivity, walkability, and sustainability in Middle Eastern cities. The localized, data-driven approach not only provides practical solutions for improving urban design but also generates valuable insights for policymakers aiming to create more vibrant and livable urban environments. Additionally, employing space syntax analysis prior to implementing the design is not a common urban design procedure in Iran, highlighting the innovative nature of this research. The outcomes of this study may inspire urban management to incorporate similar analytical methods prior to executing designs in other parts of the city as well.

Theoretical Background

Evolution of Urban Transportation and the Emergence of "Complete Streets"

For centuries, cities were structured around walking as the primary mode of transportation, giving rise to the concept of "walking cities". However, since 1850, transit urban fabric has emerged through the development of trains and later trams, bringing about distinctive expansions in cities. The rise of Automobile Cities after the 1950s, driven by car flexibility and extensive freeway construction, led to reduced densities and increased trip lengths, ultimately giving way to traffic congestion and diminishing the initial promises of speed and adaptability in automobile-based urban development. This shift has propelled a transition towards faster urban rail systems, altering the prevailing pattern of automobile urban fabric growth across cities. Hence emerged another initiative known as "Complete Streets (CS)" which aimed to "right the balance" in a transportation system that was titled towards automobiles (Lynott et al. 2009).

The inception of the CS initiative can be traced back to the 1970s, a response from the escalating dependence on automobiles in the United States following the establishment of the National Highway System (Newman and Kenworthy 1999; Schiller et al. 2010). A coalition of advocates from diverse sectors, including bicycle, transit, public health, elderly, and urban design, integrated around the idea that streets should serve more than just moving cars and the term quickly grew to encompass planning for other transportation modes (Zavestoski and Agyeman 2014). This led to a paradigm shift in street design, prioritizing pedestrian circulation over automobiles (Bry Sarte 2010) and the creation of streets and thoroughfares that accommodate the multifaceted needs of all users by various modes of transportation; Whether pedestrians, cyclists, motorists, or users of public transit, CS aspire to provide safe and accessible transportation options for all, fostering inclusive urban spaces (National Complete Streets Coalition 2020). It emphasizes inclusivity for diverse user groups, spanning different economic spectrums, individuals with disabilities, and elderly citizens (Smart Growth America 2015; Litman 2015).

This initiative seeks to redefine the purpose of streets and how communities allocate funds for transportation. By an integrated transport features like bike lanes, sidewalks, and crosswalks, the CS movement aims to enhance the functionality of roadways and foster the development of a well-connected network. This approach promotes various modes of transportation, creating a shift towards a healthier and more active lifestyle (Smart Growth America 2015). Moreover, CS advocates for a mixed land-use approach, integrating offices, retail establishments, businesses, and residential spaces to foster safe and balanced streets, supporting a diverse range of economic, cultural, and environmental activities (Burden and Litman 2011; LaPlante and McCann 2008; Seskin et al. 2012). CS policies aim to transform inadequate and limited streets into a comprehensive, self-sustaining network that serves the diverse needs of the community.

The term "Complete Streets" introduced in 2003 by David Goldberg of Smart Growth America during an America Bikes meeting as a replacement for the unwieldy term "routine accommodation", which was previously used to describe the incorporation of bicycles into regular transportation planning (McCann 2010). Later on, a diverse range of organizations, including America Walks, the American Public Transportation Association (APTA), the American Planning Association (APA), the Institute of Transportation Engineers (ITE), the Natural Resource Defence Council (NRDC), and AARP, united under the National Complete Streets Coalition. Together, these organizations have played a crucial role in reshaping the concept of CS to be inclusive, ensuring its functionality for all users, irrespective of age and ability (Lynott et al. 2009). CS shares commonalities with established U.S. policies such as liveable streets (Appleyard 1980), traffic calming (Ewing and Brown 2009), and road diet (Burden and Lagerwey 1999; Knapp et al. 2014) and aligns with urban planning initiatives such as "Living Streets," "Inclusive Streets," and "Streets for Everyone" to design streets that are safely shared by pedestrians, cyclists, and low-speed motor vehicles, often being used interchangeably with these terms.

Defining Complete Streets: Characteristics and Features

Complete Streets (CS) epitomizes an urban design philosophy focused on ensuring the safety and accessibility of all users, irrespective of their mode of travel or physical abilities (National Complete Streets Coalition 2020). While safety is its primary emphasis, CS extends beyond this by incorporating designs and policies that address social and environmental objectives (National Complete Streets Coalition 2012; Litman 2015). Moreover, the holistic approach encompassed by CS policy extends beyond mere infrastructure; it encompasses landscape design, architectural aesthetics, and urban amenities, collectively converging to produce vibrant, sustainable, and people-centric urban environments. It's essential to underscore that there is no rigid blueprint for Complete Streets; however, an exemplary CS includes crucial elements as follows (Smart Growth America 2015; Litman 2015):

- Lower traffic speeds,
- Easily accessible and wider sidewalks,
- Universal design features,
- Bus bays and shelters,
- Bike lanes and paths,
- Public transportation stops,
- Roundabouts,
- Secure crossing points, and medians,
- Crosswalks with pedestrian refuge islands,
- Thoughtful landscaping.

Impacts and Dimensions of Complete Streets: A Comprehensive Review

The current body of literature on CS involves in-depth investigations into various aspects. Ongoing research on the multifaceted impacts of CS is expanding, with initial focus centered on "safety" considerations for pedestrians and bicyclists (National Complete Streets Coalition 2012; Litman 2015; Dock, et al. 2012; Sanders et al. 2011). Scholars documented how specific features like crosswalks, pedestrian signals, improved sidewalks, and bike lanes enhanced safety, encouraging usage. On another note, studies by (Carr 2011; Dock, et al. 2012; Kingsbury et al. 2011; Litman 2015) and (National Complete Streets Coalition 2012) explore the impact on "livability" factors, not only focusing on usability and comfort of the public outdoor space, but also by showcasing "economic benefits" that gained attention, with research of (Smart Growth America 2012; Lynott et al. 2009; Litman 2015; Jensen, et al. 2017; Carr 2011). These researches also pinpointing "walkability", indicating that a walkable environment can boost business and increase property values. This shift in focus led to studies exploring positive economic dimensions, retail sales impact, and the overall economic benefits of CS policies. CS brings not only the economic benefits but also "social equality" in terms of equal accessibility for all, especially, elderly and disabled users. To promote sustainable urban development, it is essential to ensure that the process of urban design and planning adheres to principles of full accessibility for all users, particularly those who have historically faced spatial discrimination (Borowczyk 2018). Studies report that one-third of 80 state and local CS policies explicitly address the needs of older road users (Lynott et al. 2009). There are other analyses of policies, well-documented by researchers like (Burden and Litman 2011; Young 2017). It extends to scrutinizing project implementations and their economic and social impacts, as explored by (Perk et al. 2015). Additionally, scholars like (Zavestoski and Agyeman 2014; Jensen, et al. 2017; Bas et al. 2023) have contributed to the understanding of changes in non-motorized trips and shifts in transportation modes through thorough studies and direct observations. There is ample evidence supporting the advantages of redirecting attention in transportation planning from private motor vehicles to active modes of travel such as walking and bicycling. This shift promises to alleviate congestion, minimize noise pollution, reduce air pollution, lower accident rates, and improve public health outcomes (Rabl and Nazelle 2012; Rissel 2009; Sælensminde 2004). Walking, cycling, shared, intermodal, and public Transport use fewer resources and have a significantly lower environmental impact compared to motorized individual transport, known to be sustainable transport modes (Furchtlehner et al. 2022). Hence emerged another impact of CS, "Environmental Sustainability" (National Complete Streets Coalition 2012; Peiravian and Derrible 2014; Dock, et al. 2012). Sustainable forms of transport, such as walking, cycling, shared, intermodal and public transport consume fewer resources and affect the environment significantly less than motorized individual modes of transport. The literature also incorporates insights into modelling and planning tools adopted by agencies, as suggested by scholars such as (McCann and Rynne 2010; Carter, et al. 2013).

Methodology

Contemporary urban design faces numerous challenges, which will only become more complex in the future. To address these challenges effectively and minimize the risk of failure, new methods of urban design are required. These approaches should be rooted in evidence-based analysis and thorough investigation. This article used one of this kind of methods and argues that the urban design process can benefit significantly from analytical approaches, particularly those based on spatial configuration (Karimi 2012). The configuration of space affects how people perceive, navigate, and utilize different environments, from small domestic areas to large urban settlements (Hillier 1996a, b; Hillier and Hanson 1989; Karimi 2012; Hanson and Hillier 1987).

Space Syntax

The methodology presented in this research aims to examine the impact of proposed urban design interventions for Haft-e-Tir Square based on CS policies. Thus, we needed a tool to study the urban morphology of Haft-e-Tir Square. Urban morphology allows us to analyze and design urban environments by integrating physical forms, spatial configurations, and human interactions into cohesive urban models. This methodology uses quantitative spatial models to bridge the built environment with social and behavioral complexities, enabling innovative and informed urban design (Karimi 2023).

A practical tool for space planning and design which provided essential theoretical and technical support for studying urban morphology and showing how planning and design decisions fundamentally impact how people move, interact, and transact in cities is "space syntax (SS)". Space syntax explains the logic of society by manifestation in spatial systems. It facilitates the identification and quantification of diverse morphological features, enabling the production of research outcomes with mathematical precision through formal models (Hillier and Hanson 1989; Hanson 1989). By rethinking spatial order, SS provides a systematic approach to analyzing spatial layouts, illustrating the complex interaction between localized morphological connections and larger spatial configurations. Its adaptability allows for a comprehensive analysis of urban dynamics and informs effective planning decisions (Hillier 1996b).

Moreover, it not only explains and predicts human behaviour and its consequences, but also tests planning and design ideas from early conceptual stages through to detailed design and in-use performance. It assists architects and urban designers in elucidating and forecasting forms, as well as visualizing the complex underlying structures of architecture and urban spaces (Hillier 1993). It allows for evaluating the potential vitality of future streets by considering spatial integration values and land use intensity. Through the analysis of spatial conditions, designers can create effective urban designs, drawing insights from the concealed spatial structures uncovered through SS analysis, which assists in decision-making for urban planning and design (Karimi 2012).

The assessment of urban design proposals has been significantly enhanced by the valuable insights that the emergence of SS had provided since 1970(Hillier 1996b). By embracing an evidence-based spatial analysis method, future urban design proposals can be comprehensively evaluated by SS, directing attention toward upcoming urban design initiatives (Pilkington 2020). As a result, the Space Syntax (SS) approach enables designers to make well-informed decisions regarding the planning, design, and operation of spaces (Space Syntax Limited© n.d.) and offers detailed analyses of the spatial configurative changes introduced by design proposals (Yamu et al. 2021). Therefore, this research can benefit from this feature of SS to further analyze the design proposal created based on CS policies and then compare the result to bring about a new understanding of CS influences on urban morphology.

How Space Syntax Used in this Study

In this research, DepthmapX, a computer program based on SS methodology, was used to visualize and quantify the street network spatial hierarchies of Haft-e-Tir Square. This tool has been utilized by various authors in morphological urban studies (Xia et al. 2016, Koohsari et al. 2016). DepthmapX enables quick and easy data processing without requiring specialized knowledge or technical expertise, and it provides a direct visualization of the spatial hierarchy of the street network.

The syntax model concurrently analyzes pedestrian, bicycle, and vehicle movement networks (Space Syntax Limited© n.d.), offering a deeper understanding of urban grid structures and their relationship with urban functions (Hillier 1996a, b). It also explains key relationships between spatial location, spatial connectivity, and urban performance outcomes including land value, and physical and mental health. Moreover, SS assesses the configuration of the street network across various scales, tailored to the dimensions of the research area. Since the objective of this study is to evaluate the impact of CS policies on an urban square, we opted to analyze a buffer zone extending 250 m from the square. This buffer allows for a comprehensive analysis of the surrounding area, capturing potential influences on the square from its immediate vicinity.

Limitations

While Space Syntax (SS) analysis is crucial for evaluating urban design interventions, it tends to prioritize geometric and topological aspects over socio-cultural factors, sometimes missing elements like local identity in Haft-e-Tir Square. It provides insights into movement patterns but may overlook the area's unique characteristics. Despite these limitations, they haven't significantly affected the outcomes of this study. We're addressing this by integrating qualitative field research methods alongside Strollology (Burckhardt 2015). Strollology, often called the science of walking, focuses on how people perceive their surroundings in sequences (Fezer and Schmitz 2012, p. 239). Strollology encourages slow, deliberate observation and engagement with the environment and its users. This approach fosters a deeper awareness of the social, cultural, and sensory dimensions of landscapes. In this study, Strollology will complement SS findings by exploring local preferences and nuances through direct data collection. This combined approach validates SS results and provides deeper insights into Haft-e-Tir Square's form and function, enriching our understanding of the area.

Additionally, SS analysis does not provide specific guidelines for optimal design solutions. Instead, by evaluating various spatial possibilities, it facilitates the prediction of potential effects on urban dynamics, considering contemporary spatial theories (Karimi 2012). This process overlooks factors like terrain slope, weather conditions, and cultural aspects of biking that may affect the area. To mitigate these limitations, qualitative field observations in addition to "Walking and Observing[1]" were integrated into the research. Haft-e-Tir Square was explored by the researcher, gathering information on building types, land use, transportation systems, and social dynamics. This hands-on approach provided valuable insights into the area's physical and spatial characteristics, capturing nuances such as terrain incline and cultural influences on biking habits, and ensuring a comprehensive understanding of the urban environment.

The study also faced challenges with data availability and accuracy for Haft-e-Tir Square and its surroundings. Standard sources like OpenStreetMap were insufficient and inaccurate. This necessitated the integration of more personal observations and qualitative insights to supplement SS analysis and add depth and context to findings.

Despite acknowledging the limitations of SS analysis, the methodology retains significance through its alignment with CS policy, primarily focusing on physical interventions. These constraints do not diminish the overall integrity and value of the research outcome when combined with field observation. Employing a mixed-methods approach can help compensate for any shortcomings. Incorporating spatial mapping and urban fabric analysis, and qualitative observations, this study aims to comprehensively explore the influence of spatial configuration on an urban neighborhood.

Analytical Framework

Baseline Assessment

Firstly, we carefully observed, mapped, and assessed the current situation at Haft-e-Tir Square using both Strollology and traditional observation methods. During this phase, we gathered information on traffic flow, pedestrian movements, and identified key nodes within the transport system. This initial observational data formed the foundation for our baseline analysis. A set of analytical investigations then, referred to as a 'baseline analysis,' was conducted. The baseline analysis aimed to comprehensively evaluate the current spatial layout and connectivity of the street network in the study area. To achieve this, Space Syntax (SS) metrics such as integration, choice, entropy, and connectivity were employed. These metrics provided quantitative insights into how the urban space functions in terms of movement and accessibility.

Alongside SS analysis, Strollology played a crucial role. This approach involved taking deliberate, unhurried walks through the square and its surroundings. It aims to track down specific landscape or urban images (Amistadi, et al. 2022) in order to understand how people perceive and interact with the environment on a deeper, qualitative level, capturing social, cultural, and sensory dimensions that SS metrics may not fully capture. The Strollology observations in Haft-e-Tir Square highlighted the profound influence of the square's architectural and spatial organization on social interactions and cultural dynamics. This method provided valuable qualitative insights that complemented the quantitative data from SS analysis, enriching the overall understanding of the area's human experience (Fig. 2).

Design Proposal Evaluation

The design proposal used for the analysis of this study was crafted by a graduate student in an environmental design studio as part of their task. Given the square's current auto-centric layout, students were tasked with devising innovative design strategies rooted in CS policies. Their emphasis lies on prioritizing pedestrian and cycling infrastructure to tackle traffic congestion, mitigate air pollution, and advocate for sustainable transportation modes. Moreover, they were asked to refine the traffic and population nodes in the current layout of the square. Visualizations, including maps, diagrams, and renderings, were gathered from student project aligning with CS principles.

[1] Strollology, or Promenadology, regards walking and observing as fundamental methods for exploring and understanding the environment. Developed by Lucius Burckhardt and expanded upon by scholars like Tim Ingold, Strollology views walking not just as a means of transportation, but as a deliberate practice for immersing oneself in landscapes, urban areas, and natural settings. It emphasizes the sensory engagement and embodied experience of walking, encouraging individuals to slow down, perceive details, and reflect deeply on their surroundings. Through this method, Strollology aims to uncover the richness of environments, revealing hidden meanings and fostering a profound connection between individuals and their surroundings.

Subsequently, the same analysis conducted in the previous phase was applied to evaluate this design proposal (Fig. 3).

Comparative Analysis

The morphology of the current layout of the square is compared with the design proposal. Metrics such as local and global integration, connectivity, and other relevant factors obtained from the SS analysis of the current situation compared with those of the proposed design. This comparison serves to illustrate the influence of CS policies on the urban fabric of Haft-e-Tir Square. By examining how these metrics change between the current state and the proposed design, we gain insights into the potential impact of implementing CS principles on the spatial configuration and functionality of the square.

Introducing the Study Area: Haft-e-Tir Square

Location of the Area

Haft-Tir Square, spanning over 33,000 square meters, is one of Tehran's vibrant, centrally located commercial hubs, situated within the boundaries of the sixth and seventh districts. Formerly known as "Shahrivar 25," the square's positioning in seventh districts of Tehran, surrounded by a variety of shops. Haft-Tir Square also hosts essential public transport facilities, including subway stations, bus stops, and a shared taxi station. Its strategic location connects it to major thoroughfares such as Modarres Highway, Mofatteh Street, Bahar-e Shiraz Street, and Karim Khan-e Zand Street. The area is encircled by

Fig. 2 Haft-e-Tir Square's Strollology

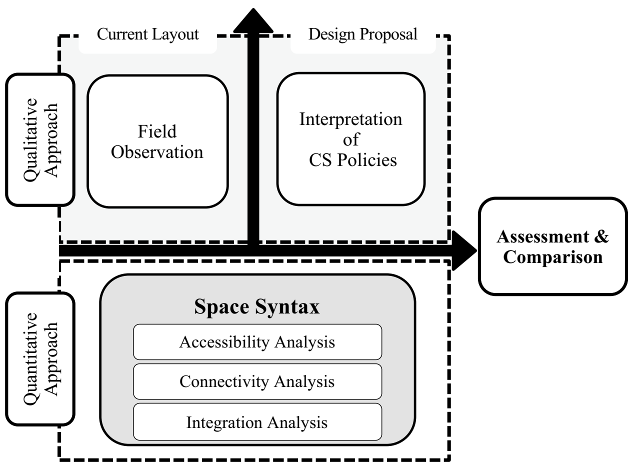

Fig. 3 Methodological framework of the research

a mix of residential and commercial properties, making it a significant node in Tehran's urban landscape (Fig. 4).

Demographic and Social Aspects

The neighborhood around Haft-e-Tir Square has a diverse population, attracting many due to its central location and extensive amenities. It is a vibrant hub in Tehran and attracts numerous residents due to its easy access to various parts of the city. This demographic diversity contributes to a vibrant and active community with a potential for pedestrian-friendly initiatives. The area around Haft-e-Tir Square boasts a high literacy rate, supported by numerous educational institutions. There is also a significant employment rate, with many residents engaged in various commercial, service-oriented, and professional activities.

Morphological Aspect

Haft-e-Tir Square exhibits a diverse morphological aspect. With a slight incline of 2.3% and a 12-m elevation difference between its highest and lowest points, the square's terrain adds complexity to its urban fabric. The elongated shape of the square, measuring almost 500 m in length and 50 m in width, contributes to its dynamic spatial configuration. Its morphological diversity extends beyond its physical features to encompass its land use composition. The blend of residential, commercial, and service-oriented establishments within the square reflects its multifunctional nature and vibrant urban character. From bustling commercial activities to cultural landmarks, the square's morphological aspect reflects the diverse needs and aspirations of its inhabitants. The square relies mainly on subway, bus, and taxi services, with limited parking facilities available. Congestion is notable, especially in the southern area where key attractions and transport hubs are concentrated (Fig. 5).

The square's morphological aspect plays a significant role in shaping its urban character and functionality. The gentle incline and elevation difference contribute to the overall

Fig. 4 Left: Land-use and Access Map, right: Photography of the square by www.tehranpicture.ir

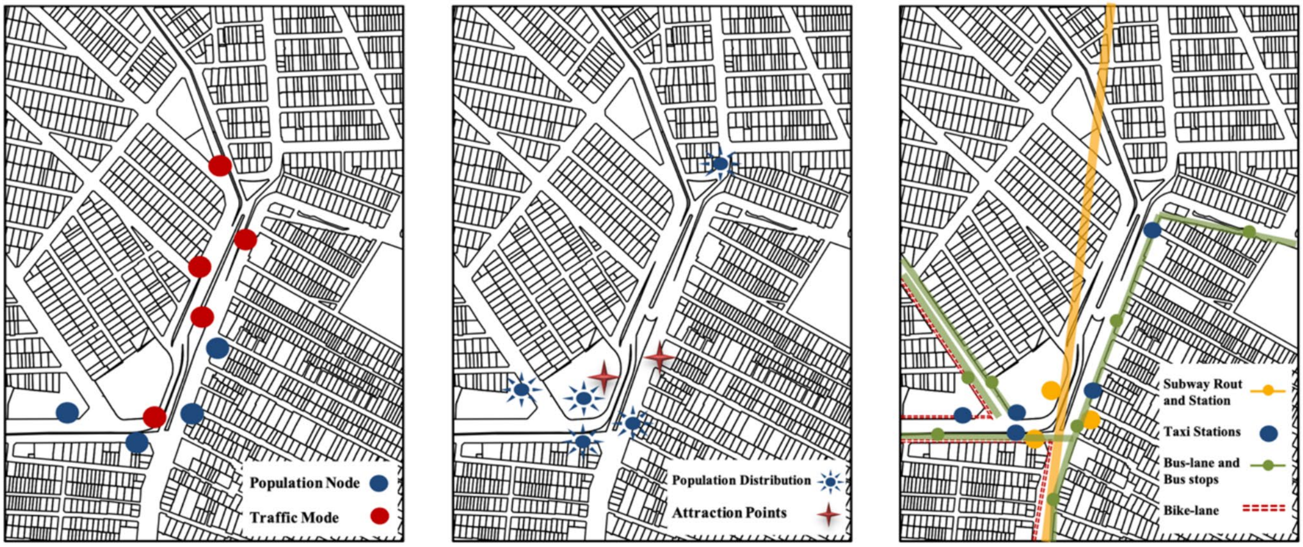

Fig. 5 Field Observation data of Haft-e-Tir Square

topographical diversity of the area, influencing pedestrian movement patterns and spatial organization. Additionally, the elongated layout of the square enhances its connectivity with surrounding streets and neighborhoods, facilitating ease of access for residents and visitors alike.

Communicational Structure and Access Network

Block Pattern

Haft-e-Tir neighborhood encompasses a layout comprising homogenous blocks. These blocks are typically organized in a grid pattern, facilitating movement and access throughout the neighborhood.

Mass and Space System

The ratio of open spaces to build-masses (including buildings and greenery) within Haft-e-Tir Square is a crucial aspect affecting accessibility, pedestrian movement and climate friendly environment. A balanced distribution of open spaces and built structures promotes ease of movement and encourages pedestrian activity. Conversely, a disproportionate ratio may hinder accessibility and reduce the inclination towards walking (Fig. 6).

Spatial Organization

The spatial organization of Haft-e-Tir Square includes key elements such as main thoroughfares along the periphery, primary circulation routes within the neighborhood, and commercial service areas. These elements contribute to the neighborhood's functionality and attract a diverse population. Additionally, the presence of public transportation stations, functional intersections, and focal nodes further enhances the accessibility and connectivity within the area. Historically, Haft-Tir Square has served as a crucial link in Tehran's urban fabric, fostering the development of trade guilds and a robust public transportation network. However, over time, increasing traffic congestion, both from private and public transport, has posed significant challenges, prompting several layout changes in attempts to alleviate the issue. Given the current auto-centric layout of the square, implementing design strategies rooted in multi-transport options such as CS holds promise for addressing many of these challenges.

Results and Findings

As extensively detailed previously, DepthmapX employed as a software to conduct the analysis of the urban fabric before and after implementing CS strategies. In DepthmapX we generated the axial map, a fundamental tool for urban space analysis. The axial map represents the portions of urban space that are visually observable and physically accessible (Marcus 2007). Through the axial map, we are able to abstract and simplify the complexity of reality (Van Nes and Yamu 2021). This method efficiently represents the spatial network using a network of lines, making analysis simpler. The advantage of this model is that it produces a straightforward depiction of the spatial network, directly reflecting how people perceive (visibility) and navigate (movement) through the network (Karimi 2012).

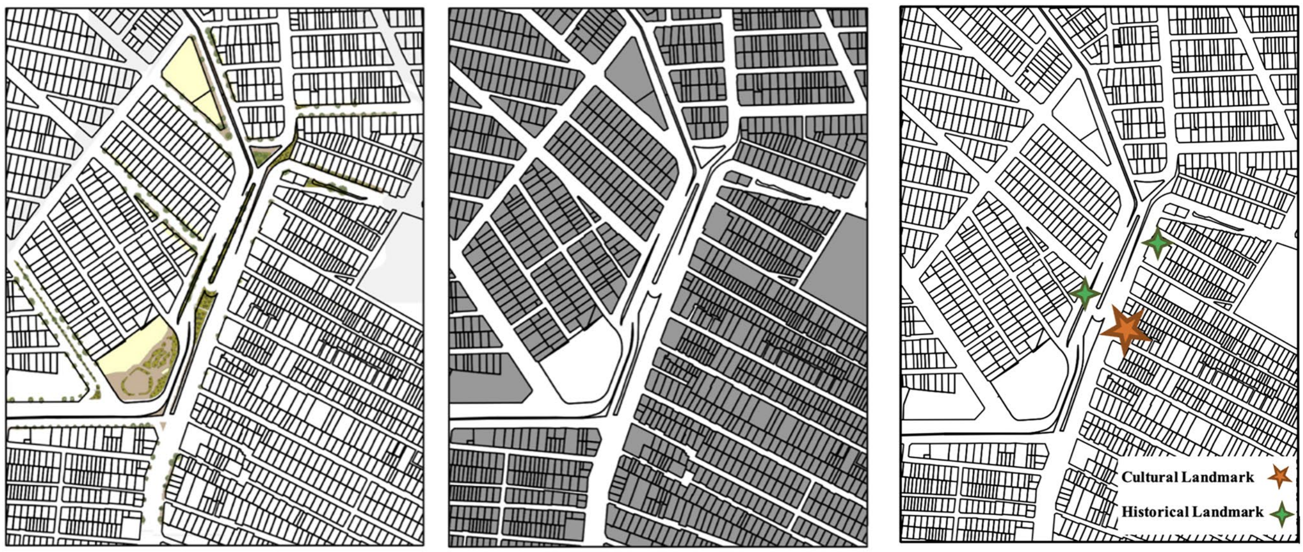

Fig. 6 from left: Green space ration, Mass-Space map of Haft-e-Tir square, Landmarks

Thus, in this analysis, we initially converted the urban fabric of the current square layout into axial lines to compute integration and connectivity values for each street in the study area. The software generates colored maps, visualizing low and high values using a color range. Streets with higher values are highlighted in red and yellow, while those with lower values appear in darker blue and green tones.

When analyzing space, it is crucial to recognize that "The most fundamental, yet simple, attributes of space are used to create space syntax models: people move in lines, perceive the built environment through 'visual fields,' and gather in 'convex' spaces (Karimi 2012, 10). "Focusing on these basic aspects makes understanding and comparing spatial morphology much simpler".

Current Conditions

Current Layout: Connectivity and Choice Analysis

A connectivity analysis performed on the current layout reveals that the southern to northern section of the square exhibits high connectivity, as evidenced by a high node count and choice values. Conversely, the North to South Street demonstrates fewer connections, resulting in a lower connectivity value. This pattern extends to the surrounding streets, notably Karimkhan-e-Zand Street, which shows lower connectivity, particularly on the segment exiting the square. Generally, all streets exiting the square exhibit lower connectivity compared to those entering it, except for Bahar Shiraz Street, which maintains high local integration.

In addition, the high choice values for South to North Street and North to South Street indicate that these streets are frequently selected as part of the shortest paths in the network, underscoring their critical role in facilitating movement and traffic flow.

Figure 7 (a) presents the n-step connectivity analysis, also known as a point-depth analysis, demonstrating the topological depth of all streets and roads in the network of the study area. This typically assesses the effectiveness of the public transport stations network in covering the city in terms of direction changes. Figure 7 (b) shows the 2-step analysis of connectivity, illustrating the degree of accessibility to the surrounding neighbourhood, suitable for analysing pedestrian flow and accessibility within an urban area. Based on Fig. 7 (b), it becomes evident that a considerable portion of the urban fabric surrounding the square is interconnected using the 2-step method. This suggests that there is ample opportunity to improve pedestrian pathways, particularly in the southern to northern section of the square. By improving pedestrian infrastructure in this part, the local shops of the square will benefit from increased foot traffic and accessibility, showing greater economic activity and vitality. Creating pedestrian-friendly environments can enhance the overall urban experience, social interaction and community engagement.

Thus, leveraging the connectivity observed in Fig. 7 (b) presents a promising avenue for enhancing both the economic and social fabric of the surrounding urban area. Figure 7 (a) also demonstrates that the southern to northern section of the square is strategically positioned to accommodate public transport infrastructure, making it suitable for locating entrances to metro and bus stations. Such placement can enhance accessibility to public transportation, facilitating easier commuting for residents and visitors, which is a critical option in commercial areas.

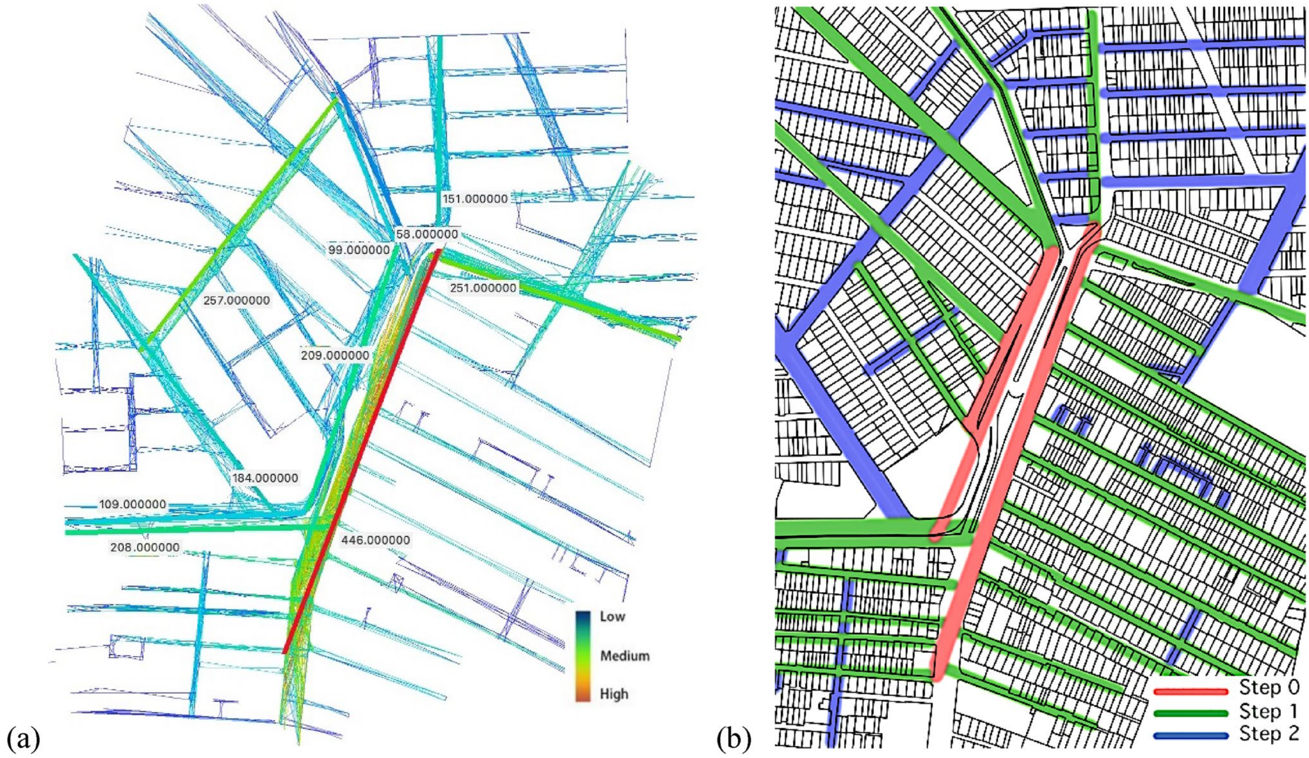

Fig. 7 Connectivity analysis **a** n-step, **b** 2-step

Current Layout: Integration and Entropy Analysis

The integration analysis, supported by entropy measures, reveals that the square itself exhibits high variability in movement patterns, contributing to its role as a central hub for commercial activity. It is centrally positioned and well-connected, as depicted in the integration map, highlighting the square's significance as the primary focal point of commercial activity. This variability enhances connectivity to potential customers and neighboring businesses, fostering economic vitality. Utilizing integration analysis, we assessed movement efficiency and identified the spatial hierarchy within the urban fabric. Our findings indicate that the square effectively leverages its high integration for commercial purposes, ensuring connectivity to potential customers, neighboring businesses, transportation hubs, and amenities. This connectivity enhances foot traffic and visibility, contributing to increased commercial activity.

As pictured in Fig. 8 (b), the local integration analysis indicates higher integration values, particularly along the southern to northern axis of the square, suggesting suitability for pedestrian activities. Conversely, the global integration analysis (Fig. 8 (a)) reveals that the southern to northern and northern to southern lines both are suited for public transportation infrastructure.

Another intriguing observation in the current layout is the variation in integration values of the adjacent street to the square when analyzed locally. Mashahir Street, as depicted in Fig. 8, exhibits a notable shift in local integration values rather than global ones. This street demonstrates high integration within its immediate vicinity, indicating its critical role in local circulation. However, its low global integration suggests that despite its local importance, Mashahir Street does not serve as a major connector within the broader city transportation network. Instead, it primarily caters to local traffic and has minimal impact on through traffic or regional connectivity. Moreover, entropy values indicate the variability and predictability of movement through these streets. Higher entropy values on streets like South to North Street suggest a diverse range of routes passing through, enhancing its role as a significant connector. In contrast, lower entropy values for streets like Karimkhan-e Zand highlight a more predictable and less varied use, which aligns with their lower choice values.

To summarize, the analysis of the street network using DepthmapX reveals distinct patterns in connectivity, choice, entropy, and integration across different streets within the current layout of Haft-e Tir Square. According to Table 1, primary thoroughfares like South to North Street and North to South Street of the square emerge as pivotal routes with high connectivity, indicating their essential role in

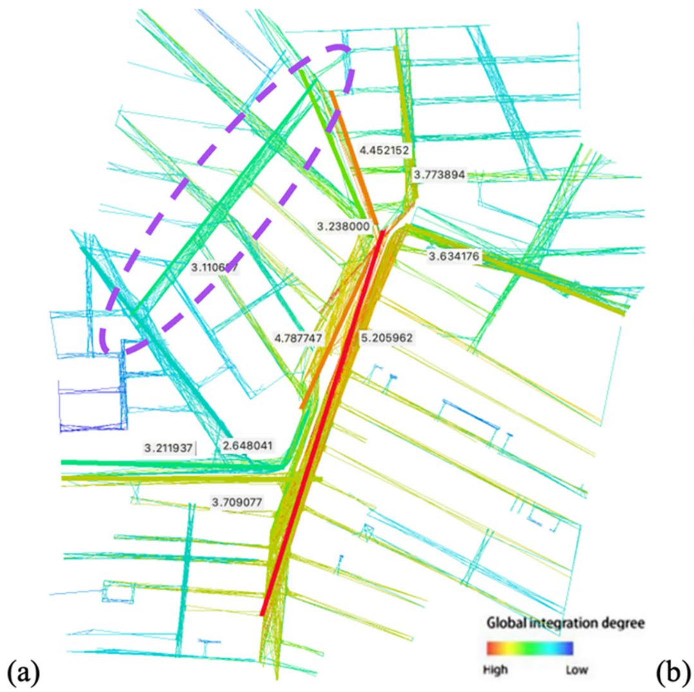

Fig. 8 **a** Global Integration analysis, **b** local R-3 Integration analysis

Table 1 Summary of current layout's attributes

	Connectivity	choice	choice [Norm]	Entropy	Integration [HH]	choice R3	choice [Norm] R3	Entropy R3	Integration [HH] R3
South to North Street	390	229,897	0.0985	2.19722	5.22	33,545	0.0220	1.54023	6.87112
North to South Street	119	225,498	0.0967	1.92059	4.78775	23,742	0.1655	1.56434	8.04968
To Karimkhan-e Zand	107	29,252	0.0125	2.31193	3.21306	1,596	0.0037	1.37807	5.16698
From Karimkhan-e Zand	217	3,031	0.0012	2.4754	3.70908	419	0.0005	1.45186	5.7474
Bahar-e Shiraz	238	14,222	0.0060	2.62209	3.63418	2,108	0.0028	1.50816	6.64437
Mofateh north	144	22,543	0.0096	2.12124	3.77312	2,064	0.0022	1.18239	4.94262
To Modares	79	37,577	0.0161	1.97072	4.45107	10,464	0.0073	1.21444	5.4645
From Modares	99	5,306	0.0022	2.32208	3.238	1,588	0.0037	1.38352	5.4086
Mashahir Street	262	29,846	0.0128	2.51892	3.11175	7,437	0.0236	1.54083	7.81035
Lotfi Alley	139	47,420	0.0203	2.17916	3.71133	5,730	0.0072	1.29563	5.13673

facilitating traffic flow. These streets also exhibit significant choice, highlighting their importance as critical paths in the network. In contrast, secondary routes like Lotfi Alley play a supportive role with moderate connectivity and choice values, providing alternative paths within the network.

Streets like Mashahir Street and Bahar-e Shiraz show high local integration, highlighting their importance in localized contexts. In contrast, both the inbound and outbound routes of Karimkhan-e Zand have lower choice but moderate integration, suggesting they are less central to traffic flow but still play a significant role in the network.

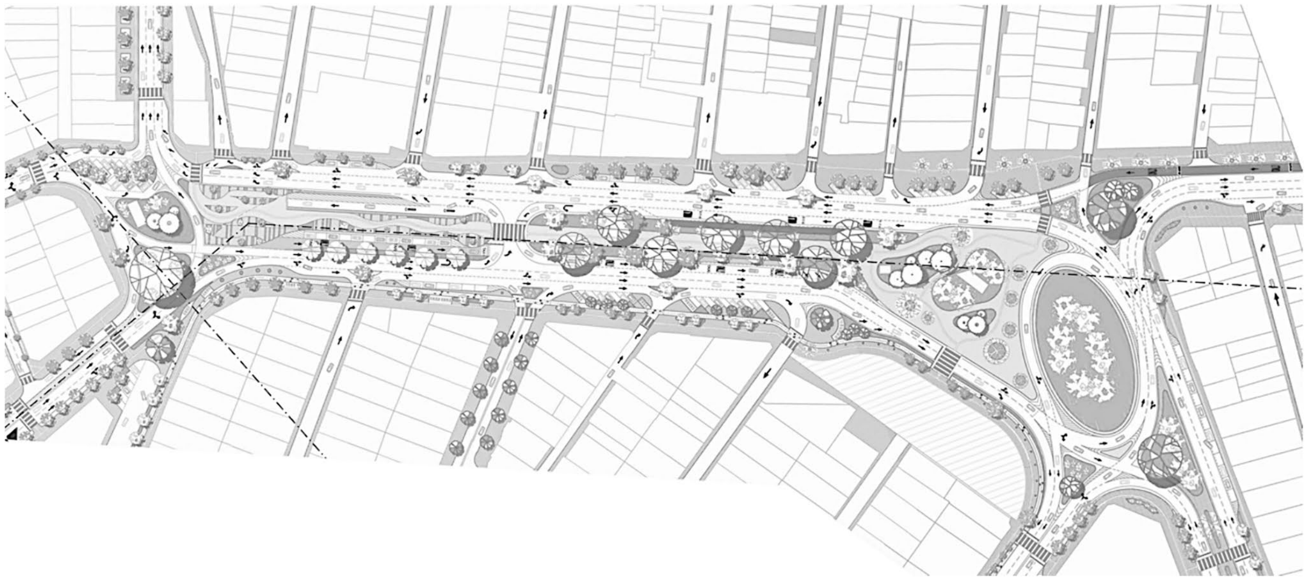

Fig. 9 The Design Proposal Layout (Designed by one of the graduate students of Environmental Design Studio)

Presentation and Assessment of Design Proposal based on CS Policies

The design proposal was crafted based on CS design strategies in an environmental design studio at University of Tehran. This design proposal took into account various parameters as introduced in the 2.2 section (Defining Complete Streets: Characteristics and Features). The design proposal, as planned, embodied the principles of CS in its morphology. It decreased traffic speed through strategic traffic line design and the relocation of roundabouts, while also establishing safe crossing points and medians. Additionally, it widened sidewalks to improve accessibility and enhanced walkability through creative landscaping initiatives.

Furthermore, the design introduced bus bays and bike lanes to facilitate integrated modes of transportation within the area which was absent in the current layout of the square. Importantly, existing public transportation stops, such as bus stops, metro stations, and shared taxi stations, were maintained, ensuring safe access to and from these stops. Additionally, there was a focus on addressing traffic congestion, minimizing air pollution, and promoting sustainable transportation modes to create safer, walkable, livable, and environmentally friendlier urban fabric. The proposed design layout is illustrated in Figs. 9 and 10.

Design Proposal: Connectivity and Choice Analysis

After developing the design ideas, it systematically tested using the same analytical techniques applied for baseline analysis. This approach is similar to studies conducted by Space Syntax Limited©, 2004–2006 and Cheshmehzangi and Heath 2012 on Old Market Square in Nottingham.

The design proposal layout underwent a thorough analysis of its connectivity. It highlights a concentration of high connectivity values in the southern part of the square, where vital transportation hubs converge, including metro, bus, and shared taxi stations. This strategic clustering underscores the potential to enhance accessibility and facilitate ease of movement within the urban fabric (Fig. 11).

Furthermore, an examination of choice values reveals significant shifts in traffic flow dynamics. Streets prioritized for redesign show notable changes in betweenness centrality, reflecting their increased importance as critical nodes in the urban mobility network. Enhanced choice values indicate improved efficiency in traffic routing and accessibility. For instance, South to North Street shows a substantial increase in betweenness centrality, indicating its role as a crucial thoroughfare for traffic flow and pedestrian movement. Conversely, To Kari mkhan-e Zand experiences a slight decrease in choice values, suggesting its lesser centrality despite moderate integration levels.

Moreover, Fig. 11(b) illustrates that nearly all streets around the square are accessible within a 2-step method. This indicates increased foot traffic and accessibility, leading to greater economic activity and vitality. Consequently, this design fosters more pedestrian-friendly environments, enhanced social interaction, and community engagement. Furthermore, Fig. 11(a) presents a higher connectivity level for all the streets that form the square (617–614 is the connection value of the streets forming the square).

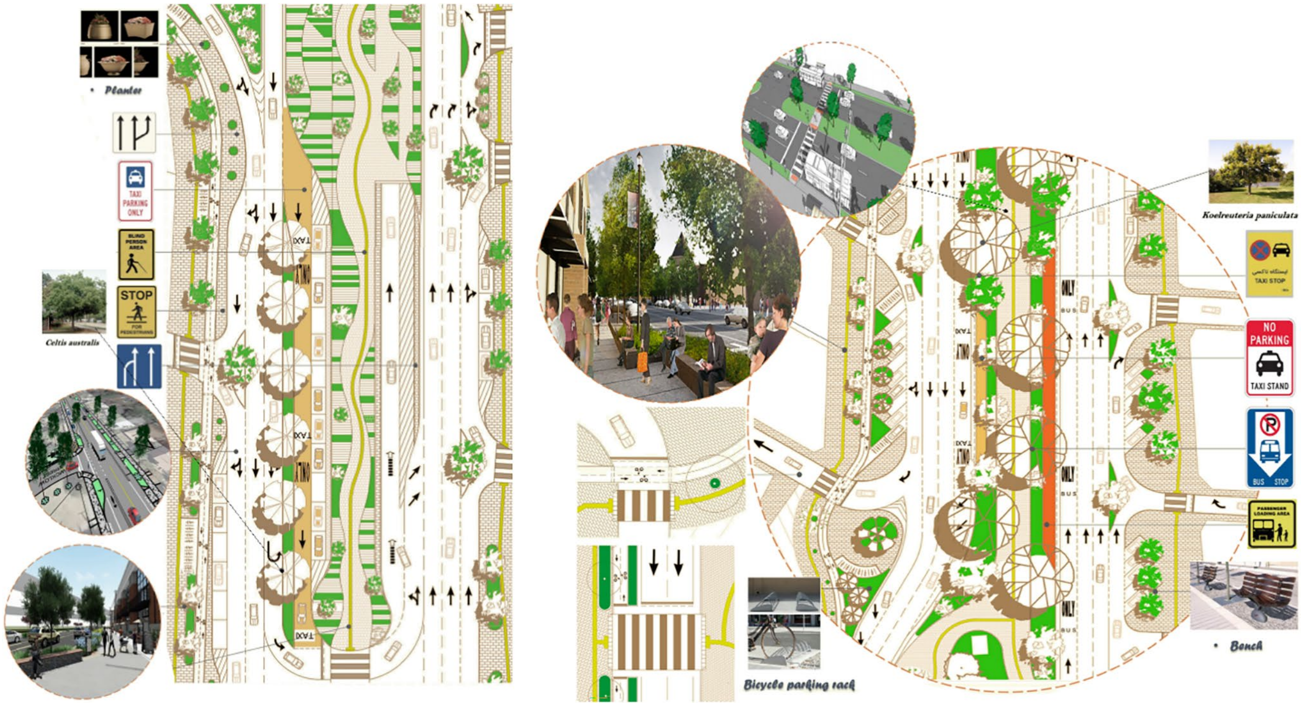

Fig. 10 The Design Proposal Details (Designed by one of the graduate students of Environmental Design Studio)

Design Proposal: Integration and Entropy Analysis

The local integration analysis of the design proposal reveals that, similar to the baseline analysis, the square itself remains the most integrated and accessible point within the urban fabric of the study area. However, the integration values of the streets within and surrounding the square have increased, indicating greater spatial integration characterized by fewer directional changes needed to reach various locations in the urban setting. Streets adjacent to transportation hubs show enhanced integration values, facilitating seamless connectivity and reducing directional changes required for navigation (Fig. 12). The alignment between local and global spatial configurations has also improved, enhancing the system's intelligibility for navigators (J. Hanson 1989; Hillier and Penn 1996).

The local integration analysis shows that the previously higher integration values along the southern-to-northern axis of the square have now increased along the northern-to-southern axis as well, suggesting enhanced suitability for pedestrian activities. Notably, the integration of streets connected to the square (marked on the map of Fig. 12) has also increased. The analysis results clearly demonstrate that the overall system's integration has been boosted by the changes in the square's layout.

In parallel, entropy analysis illustrates changes in connectivity complexity across the proposed design. Higher entropy values, observed particularly in Mashahir Street and Bahar-e Shiraz, indicate diverse and dynamic networks of pedestrian and vehicular interactions. These streets are pivotal in fostering vibrant urban activities and economic vitality, underlining their significance in the redesigned urban landscape.This complexity underscores the design's adaptability to varied urban activities and user needs.

In summary, Table 2 presents an in-depth analysis of street attributes within the urban network, focusing on metrics such as connectivity, choice (both absolute and normalized), entropy, and integration. According to Table 2, South to North Street and North to South Street of the redesigned square still stand out with high connectivity and exceptionally high choice values, highlighting their critical roles as major thoroughfares supporting extensive traffic flow. These streets also exhibit strong global integration, underscoring their centrality within the network. In contrast, streets like To and from Karimkhan-e Zand show lower connectivity and more modest choice values, indicating lesser significance in the traffic dynamics despite moderate global integration levels. Bahar-e Shiraz and Mashahir Street demonstrate moderate to high

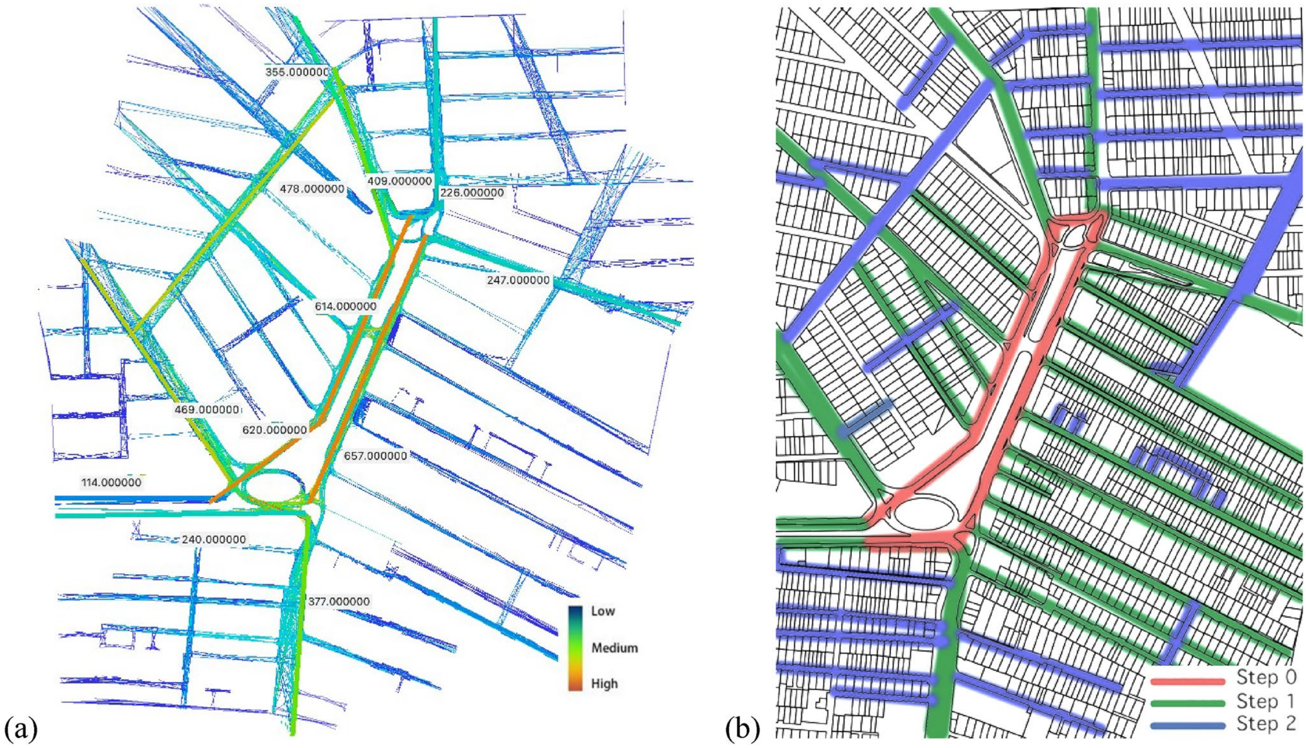

Fig. 11 Connectivity analysis of the design proposal **a** n-step, **b** 2-step

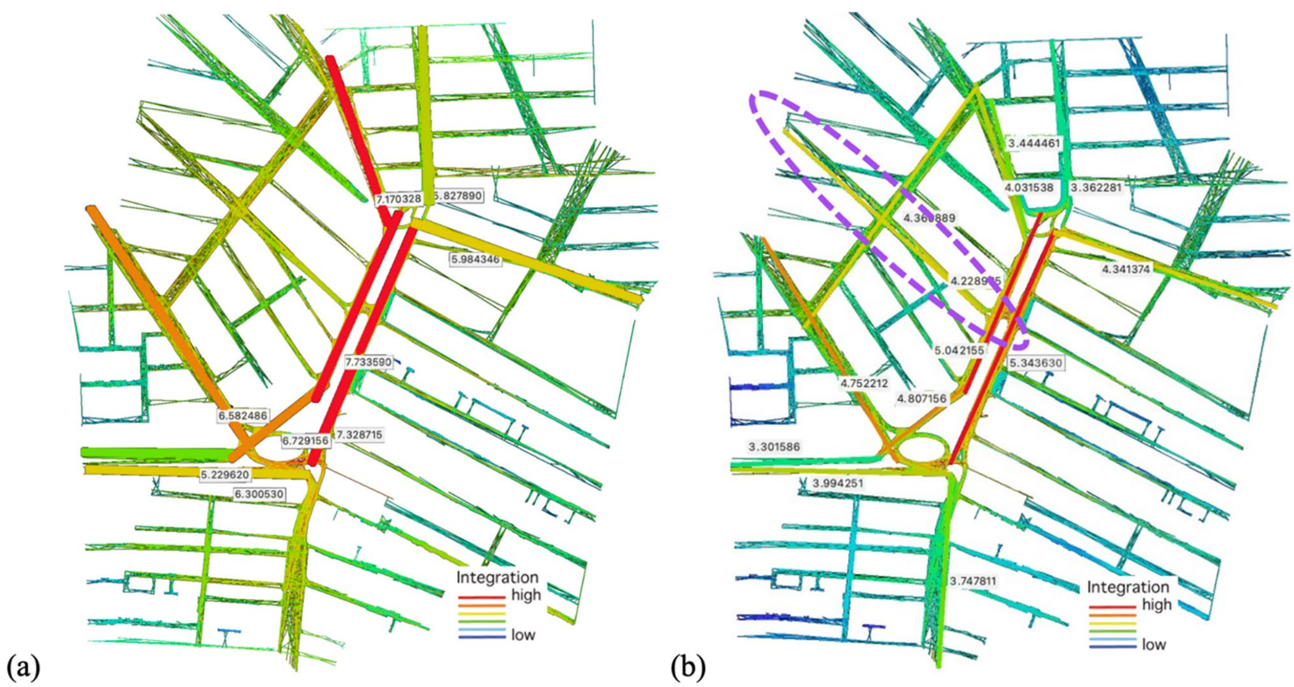

Fig. 12 Design Proposal **a** Local R-3 Integration analysis, **b** Global Integration analysis

Table 2 Summary of design proposal's attributes

	Connectivity	choice	choice [Norm]	Entropy	Integration [HH]	choice R3	choice [Norm] R3	Entropy R3	Integration [HH] R3
South to North Street	624	638,905	0.0291531	2.1324	5.34704	1.7839	101,795	0.00923878	1.42449
North to South Street	601	237,863	0.0108536	2.32809	5.04672	1.74927	54,530	0.00568613	1.42698
To Karimkhan-e Zand	125	695	3.17E-05	2.3576	3.30159	2.28646	124	6.22E-05	1.1786
From Karim-khan-e Zand	230	1,611	7.35E-05	2.34063	3.99425	2.03844	212	4.02E-05	1.29091
Bahar-e Shiraz	246	80,441	0.00367051	2.19865	4.34109	2.00885	14,870	0.0019349	1.19743
Mofateh north	225	42,911	0.00195802	2.10955	3.362281	2.10955	8,198	0.0023008	1.26778
To Modares	206	10,969	0.000500513	2.65978	3.44446	2.07675	3,607	0.000879181	1.29022
From Modares	393	157,378	0.00718112	2.57338	4.03154	1.93346	45,556	0.00656105	1.38004
Mashahir Street	478	369,775	0.168728	2.42258	4.36203	1.87046	53,786	0.00693838	1.38305
Lotfi Alley	374	71,612	0.00326764	2.37644	4.22892	1.9429	25,727	0.00342405	1.29284

Table 3 Comparison of parameters between current and proposed designs for Haft-e-Tir square

	South to North Street	North to South Street	To Karimkhan-e Zand	From Karimkhan-e Zand	Bahar-e Shiraz	Mofateh north	To Modares	From Modares	Mashahir Street	Lotfi Alley
Connectivity	390	119	107	217	238	144	79	99	262	139
	624	601	125	230	246	225	206	393	478	374
	+234	**+482**	**+18**	**+13**	**+8**	**+81**	**+127**	**+294**	**+216**	**+235**
Choice	229,89	225,498	29,252	3,031	14,222	22,543	37,577	5,306	29,846	47,420
	638,90	237,863	695	1,611	80,441	42,911	10,969	157,378	369,775	71,612
	+409	**+12,365**	**-28,557**	**-1,420**	**+66,219**	**+20,368**	**-26,608**	**+152,072**	**+339,929**	**+24,192**
Entropy	2.197	1.920	2.311	2.475	2.622	2.121	1.970	2.322	2.518	2.179
	2.132	2.328	2.357	2.340	2.198	2.019	2.659	2.573	2.422	2.376
	-0.064	**+0.407**	**+0.045**	**-0.134**	**-0.423**	**-0.423**	**+0.689**	**+0.2513**	**-0.096**	**+0.197**
Integration	2.197	4.787	3.213	3.709	3.634	3.773	4.451	3.238	3.111	3.711
	5.347	5.046	3.301	3.994	4.341	3.362	3.444	4.031	4.362	4.228
	+3.149	**+0.258**	**+0.088**	**+0.285**	**+0.706**	**+0.455**	**-1.006**	**+0.79354**	**+1.250**	**+0.517**

The current layout   The Proposed Design

connectivity and choice values, emphasizing their importance in connecting different parts of the urban landscape.

Comparison and Discussion

Now that we have conducted both the baseline analysis and analyzed the design proposal, a comparative study can provide deeper insights into the impact of CS policies on the urban fabric. The comparison of the proposed design for Haft-e-Tir Square with the current layout reveals significant improvements in urban connectivity and a more homogeneous spread of high integration areas, underscoring the effectiveness of CS design policies with careful consideration. The findings emphasizing the enhanced pedestrian flow, economic vitality, and environmental benefits observed in the redesigned urban fabric.

As displayed in Table 1, the connectivity of streets running from south to north and vice versa has significantly increased in the proposed design, suggesting an improved potential for pedestrian flow on both sides of the square. For instance, South to North Street of the square shows an increase in connectivity from 390 to 624, enhancing accessibility and traffic flow. Conversely, while some streets like

To Karimkhan-e Zand exhibit decreased choice values (from 37,577 to 695), potentially shifting traffic dynamics, overall integration values have improved across the square (Table 3). The design proposal exibit a more uniform distribution of connectivity values across these streets. In the context of Haft-e-Tir square as a commercial urban fabric, high connectivity implies enhanced accessibility and smoother movement between various shops, businesses, and amenities. Such areas are more likely to attract pedestrian traffic and foster economic activity due to their ease of access. This enhancement is likely to benefit the economic activity of surrounding shops and increase property values. Alterations in these values within the square may enhance walkability, leading to a more even distribution of shops throughout the area. This redistribution of shops could help alleviate congestion hotspots by dispersing pedestrian and vehicular traffic flow more evenly. The more evenly distributing the movement of people or vehicles, the less noise pollution of horning cars and air pollution of traffic congestions. In another word, a more uniform distribution of traffic or pedestrians will alleviate congestion or overcrowding in particular areas. Thus, the proposed design contributes to environmental sustainability by addressing congestion issues and improving traffic flow for pedestrians and vehicles. Resolving traffic flow challenges will consequently reduce congestion, noise, and air pollution, promoting a greener urban environment.

In addition, the introduction of bike lanes and bus bays in the proposed design enhances integration across the network, exemplified by increased integration values in streets surrounding the square (Table 2). Despite some challenges such as cultural norms affecting biking habits, the proposed design optimizes urban accessibility and mobility, contributing to a vibrant and livable urban environment.

Comparing the current layout analysis with the proposed design indicates that the average local integration of the study area is higher in the CS-based design, particularly on main streets like Bahar-e-Shiraz and Modares Highway, aligning with bus traffic flows, highlighting its effectiveness in promoting pedestrian flow and supporting local businesses. The higher the numerical integration value, the greater the numbers of people in the streets (Space Syntax Limited© n.d.). This improvement also increased the walkability of the urban area not only by lowering traffic speed but also by promoting less reliance on automobiles and consequently reducing air pollution.

Moreover, the global integration analysis demonstrates an increase in the integration value of the square after implementing CS strategies. This augmentation is particularly concentrated on the main streets of the square, extending further onto Bahar-e-Shiraz Street and Modares Highway, aligning with the flow of bus traffic. This enhancement suggests an improved potential for pedestrian flow and as a result social interactions on both sides of the square, thereby benefiting the economic activity of the surrounding shops and property values.

In a linear pattern commercial urban area like Haft-e-Tir square, where shops lined the streets with high connectivity to their surroundings at a short distance, shopping is predominantly convenient and efficient on foot, bicycle, or public transport. Therefore, the proposed design offers a better response to improving urban accessibility and mobility, contributing to the overall vibrancy and livability of the urban environment based on its higher connectivity and local integration and choice.

However, while the Complete Streets approach offers numerous benefits for enhancing urban safety, livability, walkability, and accessibility, it is crucial to acknowledge that it must be adapted to the unique context and needs of specific urban areas. A rigid, one-size-fits-all approach can lead to unintended consequences and fail to achieve policy objectives (D'Acci et al. 2024). In the case of Tehran's Haft-e-Tir Square, the feasibility of biking and walking is influenced by both topographical and cultural factors. The square is located in an area with minor topographical variations, featuring a 2.3% incline that may pose challenges for cycling, especially along the south-to-north path, although it remains generally manageable for most cyclists. But culturally, biking is not widely accepted for women in public areas in Tehran, which could influence the predominant use of other modes of transport in this commercial area rather than biking, particularly given its focus on women's clothing.

To present a balanced perspective on the potential of CS principles to transform Haft-e Tir Square, acknowledging a few considerations both the benefits and challenges presented:

1. **Contextual Adaptation:** The unique urban fabric of Haft-e Tir Square necessitates a tailored approach to Complete Streets, ensuring that design modifications respect local cultural, economic, and spatial contexts.
2. **Traffic Flow Implications:** Reducing road space for vehicles to accommodate pedestrians and cyclists may lead to increased congestion in the area. Analyzing traffic patterns and conducting pilot projects can help mitigate negative impacts or replace other routes for daily trips.
3. **Maintenance and Sustainability:** The introduction of new infrastructure must be accompanied by a robust maintenance plan to ensure its long-term functionality and safety. This includes regular upkeep of bike lanes, sidewalks, and green spaces that Tehran's municipality proved not to be capable of or at least sensitive about. Therefore, this might pose other challenges to the urban fabric in the long run.

4. **Effective Implementation:** Consistent enforcement of new regulations, such as bike lane usage and pedestrian right-of-way, is necessary to realize the benefits of CS. Adequate training and resources for local authorities and people living in the neighborhood can support this effort.

Conclusion

This study leveraged space syntax methodology to assess the impact of Complete Streets (CS) policies on Haft-e-Tir Square's urban fabric in Tehran. The comprehensive analysis using DepthmapX software revealed significant improvements in urban connectivity and integration following the implementation of CS policies.

The proposed design incorporates various measures such as reducing traffic speeds and enhancing safety features by repositioning roundabouts and creating adequate crossing points and medians, widening sidewalks, establishing bus bays and bike lanes and preserving existing public transportation stations. These interventions address safety, walkability, livability, and environmental sustainability by prioritizing the needs of pedestrians, cyclists, motorists, and transit riders. These measures enhanced pedestrian flow, economic vitality, and environmental sustainability, as evidenced by increased local integration values and more evenly distributed pedestrian and vehicular traffic flows. The improvements facilitate smoother movement between shops and amenities, fostering economic activity and potentially increasing property values. A more homogeneous integration suggests that shops will be evenly distributed throughout the area, mitigating congestion hotspots and easing traffic flow for both pedestrians and vehicles. This not only boosts walkability but also contributes to environmental sustainability by reducing congestion, noise, and air pollution.

Additionally, strategically relocating areas with the highest connectivity values to spots with existing transportation infrastructure, such as metro, bus, and shared taxi stations, holds promise for improving urban accessibility and mobility. This placement is anticipated to further stimulate economic activities in the study area. The comparison of local integration and connectivity values reveals that the proposed design offers a superior response to enhancing urban accessibility and mobility, thereby contributing to the overall vibrancy and livability of the urban environment.

While the DepthmapX analysis underscores the potential of CS-based design strategies to positively impact urban functionality and enhance the quality of life for residents and visitors, it is essential to adapt CS principles to the unique cultural and topographical context of Tehran. Cultural norms regarding women's cycling and minor topographical variations, such as the 2.3% incline, must be considered to avoid unintended consequences. Furthermore, the focus on axial spatial analysis may overlook crucial parameters such as land use, pedestrian hotspots, and non-axial variations in pedestrian movement, which are important for a comprehensive understanding of urban dynamics.

Recommendations for policymakers include tailored traffic flow management strategies, robust infrastructure maintenance plans, and effective implementation strategies, such as consistent enforcement of regulations and adequate training for local authorities. Addressing these considerations will ensure that CS principles effectively enhance urban safety, livability, walkability, and accessibility in Haft-e-Tir Square. Additionally, acknowledging the limitations of the applied methodology and considering broader improvements to Tehran's transportation infrastructure are crucial for effectively resolving traffic issues and achieving sustainable urban development.

Data availability The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

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