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Pedestrianization in Historic Districts in terms of Traffic, Urban Development, and Economic Perspective of Sustainable City

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ABSTRACT: Nowadays, new urban development strategies emphasize on pedestrian construction where pedestrian zones must meet the standard requirements in order to improve citizen mobility. Urban economies, social justice, and sustainable transportation may be impacted by pedestrianization. Certainly, pedestrianization and walkability can significantly reduce traffic congestion in historic and downtown districts. Concerning historical urban attitudes and relevant potentials, this paper proposes reconstructions to build better pedestrian areas in historic places where private car traffic and public transport lanes are also considered in pathway construction. As a case study, a historic area in the Iranian city of Kerman has been studied due to its unique cultural and climatic conditions. Consequently, all guidelines and regulations for changes to potential streets of historical districts into pedestrian zones have been carefully reviewed followed by defining scenarios of walkability and non-walkability (turning historic passageways into new roadways) of streets as well as improving traffic conditions. In addition to investigating variables including costs, traffic enhancement, and urban development priorities, the analysis has been done by performing the analytical hierarchy process (AHP). The results indicated that non-walkability-based scenarios (passage and roadway widening) could merely reduce delays while incurring significant expenses and the highest destruction of historic districts. Nevertheless, the analysis carried out using three criteria showed that walkability and the development of public transportation could provide the most reliable solutions (the highest point) to secure sustainable transportation.

KEYWORDS: Pedestrianization; Walkability; Urban Development; Sustainable Transportation; Sustainable City

1. INTRODUCTION

There is no doubt that transportation has become one of the most critical factors for social and economic development in cities, where the increase in traffic and travel by automobiles has created a number of social, economic, and environmental issues (Poyani & Stead, 2015). Therefore, transportation experts assert that pedestrianization and walkability can significantly reduce traffic in historic and downtown districts (Rezaei, 2022). With motor vehicles dominating human lifestyles and the rapid development of urban characteristics, pollution, traffic, and accidents have negative effects on the urban atmosphere (Carmon et al., 2003). While transportation is one of the sectors that exacerbates global warming, one of the most influential tasks to come to grips with this issue is to raise a mode shift from the use of private cars to more sustainable traffic modes, such as walking, cycling, enhancing public transport, or combinations of these (Risser and Sucha, 2020). Moreover, people have neglected their surroundings and become deprived of a sensual and spiritual understanding of their environment, eventually alienating themselves from their cities through the constant use of cars. Because walking and pedestrians have traditionally been important in transport studies, the human scale was incorporated into all urban planning. But they have been sometimes neglected in current urban planning that is usually devoted to cars and related concerns. Throughout recent decades, Kerman, a historical city located in the desert area of Iran, has seen a decline in pedestrian-specific urban spaces, and the increasing prominence of vehicles and mechanical lifestyles has left people disconnected from their historical heritage on an emotional and spiritual level (Safizadeh, 2016). The major principle of city pedestrianization is separating vehicles from pedestrians in traffic in which such separations are necessary to prevent collisions. In fact, a pedestrian zone consists of streets that are prohibited from being used by vehicles. The streets are allowed to be used by special vehicles (for example, ambulances) during specific hours, and technical services and delivery cars may be permitted to use them (Iranmanesh, 2008). Support for pedestrian mobility is expressed through the pedestrian zone. Pedestrian zones are designed to facilitate pedestrian movement safely. Sucha et al. (2017) explained pedestrian-driver interactions and decision strategies in urban areas in the Czech Republic through mixed methods research that revealed the pedestrians evaluated districts with a more balanced pedestrian/car ratio as safer. It was also suggested to make pedestrian crossings shorter, for instance, by pavement extensions as it was shown the shorter the crossing, the safer pedestrians feel. All pedestrians share the same zone in the pedestrian area. The construction solution in this zone emphasizes that the commercial and residential functions of this zone prevail over the traffic functions (EDIP s.r.o., 2008). Engineering studies on pedestrians and vehicles should be carried out in order to design walkways in a safe and efficient manner. The walkways

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can be classified according to their passage functions based on the surrounding land usage, roadway classifications (if sidewalks are part of roadways), and geometric properties. As far as functionality is concerned, the walkway is mostly used for access to neighbouring land uses or as a way to pass through (Southworth, 2006). To ensure pedestrians have the shortest feasible path, walkway widths are determined by traffic capacity, pedestrian count, and optimal service level. However, the minimum width cannot be smaller than a specified value, which takes into consideration the requirements of wheelchair users or two pedestrians safely crossing. An ideal level of service depends on the functional needs and adjacent occupancies (Southworth, 2006).

As mentioned above, the primary purpose of this research is to determine whether it is feasible to convert streets into sidewalks in the historic district of the Iranian city of Kerman. The present research is conducted by identifying measures and scenarios followed by selecting the most feasible and effective scenario. A literature review is presented in the second section to investigate the attributes discussed in the relevant studies, followed by discussions of the methodology moving toward the required analysis of the case study in the third and fourth sections. A discussion of scenario definitions and an analysis of the situation will make in the fifth and sixth sections, followed by the conclusion at the end of the paper.

2. LITERATURE REVIEW

It was in the late 1920s when pedestrian zones and practices were first introduced and scientifically studied. European cities have proposed and implemented programs to reduce the prominence of automobiles in historical zones, protect ancient spaces, and promote social life in downtowns (Khaleghi, 2018). It was during the 1960s and 1970s when pedestrian streets known as malls were established in order to provide a convenient environment for getting around and shopping in urban areas (Mofidi & KashaniJou, 2010). Afterward, one of the most influential theories proposed in this field in the 1980s is Woonerf's pattern, also known as the traffic calming measure. Woonerfs are residential streets that focus on walking and the daily lives of residents. They were mainly utilized in Germany and the Netherlands to restrict cars' speed. Meanwhile, debates on sustainable development were expanded during the 1990s. Consequently, the concept of sustainable transportation was proposed as a way of transporting people without threatening future generations. Following that, various methods of green transport enhance sustainable transportation by improving the definition of non-motorized transportation, including walking and cycling (Nalmpantis et al., 2017).

In today's world, walking and cycling are key components of sustainable mobility that contribute to the protection of the environment, superior quality of life, and greater social integration. Appearing the COVID-19 pandemic over the world, it has become even more imperative to make public spaces resilient (Domenico et al., 2022) and more popular to create pedestrianized zones in urban areas as a means of making them walkable and livable, as well as reducing pollution in urban areas by stopping cars from entering specific zones (Fournier, 2021).

According to Said and Samadi (2016), construction changes were made on the street capes in Malaysia to achieve a higher standard of living. Accordingly, pedestrian routes were designed to be tightly knitted together around historic areas. This integration was designed to make it easier for tourists to navigate through existing urban areas quickly. Based on the study, the physical change in the atmosphere of the streets contributed to the increase in public space and visitors in the adjacent neighborhoods, which contributes to sustainable urban development. Using the Analytic Network Process (ANP), Gonzalez-Urango et al. (2020) analyzed the predominant characteristics impacting pedestrian mobility in a Colombian tourist city and developed a tool for designing and planning pedestrian paths. As a result of the ANP approach, it was recommended to conduct a spatial analysis applying GIS by selecting and evaluating a set of streets near the city center, constructing thematic maps, and creating an overall measure of pedestrian preference. The design of a few important streets was also enhanced to increase their attractiveness and walkability (Gonzalez-Urango et al., 2020). Murakami et al. (2021) examined the net capitalization impacts of skyway structures and pedestrian zones in Hong Kong on office towers and retail streets. Pedestrianization's net capitalization effects on commercial properties were estimated using the hedonic regression method in this research. The models showed that skywalk networks resulted in positive capitalization effects for office units interconnected by footbridges but had little impact on street-level retail buildings. An investigation of the spatiotemporal pattern of street dynamism within a district of Beijing, China, was conducted by Li et al. (2021). This study examined its built environmental predictors for two seasons, using pedestrian traffic volume as a proxy for dynamism. It also examined the built environment as a depicted diagram by morphology, configuration, function, and landscape. It was found that pedestrians in the area are relatively distributed across the streets and have relatively high spatial concentrations, with just two flat peaks. Additionally, the winter-built environment was found to be more influential than the summer and autumn-built environments. A considerable effect of multi-dimensional built-environment characteristics, particularly urban configuration and morphology, were also demonstrated by pedestrianization and transit preference zones were analyzed by Fournier (2021) for their complementary benefits and optimal sizing. Although, transit capacity, pricing, and other important factors were not taken into consideration in this model, but the study revealed that large crowded cities with existing transit systems can benefit from the insights of such an analysis. It would also be useful to use these insights to estimate the impact of pedestrianization and transit choice in smaller cities. Pedestrian mobility has been also studied in this field, where the focus of Domenico et al. (2022) was on pedestrian mobility models across Italy, which focused on the definition of a temporal impedance function for pedestrian circulation in cities. On the basis of experimental data collected in urban districts, they proposed a calibration method for pedestrian mobility models. Pedestrian speed was also estimated as a function of pedestrian density and flow, as well as some formulations where pedestrian characteristics were determined as speed, disturbance degree, and track type.

The study by Gruden et al. (2021) introduced a model that predicts pedestrian behavior and a microsimulation model designed through Vissim/Viswalk. The model showed that crossing time predictions and micro-simulated values were highly correlated. Based on Vissim/Viswalk models, a viable prediction model could be formulated that precisely predicts pedestrian crossing times. Çınar et al. (2022) used pedestrian behavior, crossing preferences, and perceptions to investigate the behavior of pedestrians and their safety on a street in Ankara, Turkey. It was additionally intended to identify pedestrian safety concerns and Participants' attitudes, motivation, and safety perceptions were assessed using an observational study and an online survey. Car traffic and parking available spots were found to be the biggest threats to pedestrian safety, according to this research. It was also demonstrated that pedestrians who walk across the street together in a group use crosswalks and obey traffic signals more frequently than pedestrians who crosswalk on their own or in a pair. To improve pedestrian safety on the targeted street, it was recommended that vehicle traffic should be reduced, parking areas should be increased and arranged, and pedestrian facilities needs to be increased. In terms of land-use and its relevant studies to economic factors, the pedestrianization of cities and its effects on retail store revenues were examined by Yoshimura et al. (2022). To provide an overview of land-use trends at the street level, data collected by Open Street Map were combined with estimates of sales volumes across stores in Spain. After that, pedestrianization's economic impact was measured using empirical methods. There are three steps in their empirical method: gridding the city and determining the growth of pedestrian areas within each grid during an observation period, assigning different groups of grids based on the extent of pedestrian areas and their stability, and eventually applying the PSM-DID method to identify the causal effect. It was found that pedestrian-friendly stores typically record greater sales compared to other stores. Risser and Sucha (2020) investigated the motivations that can lead to an increase in walking and recommended strategies for decision-makers for promulgating changes that will boost walking. In their book, it was mentioned that enhancing walking mode could be one of the most effective steps towards sustainability. It was also discussed that an increase in the percentage of pedestrians always strengthens the local economy.

As a result of the above-mentioned points, walkway streets will be examined in the following section in relation to their attributes and the method for conducting a feasibility study. Since there are numerous attributes to consider, but little specific data has been collected, as well as concerns regarding their accuracy, the current research methodology focuses on the attributes that can be acquired realistically and precisely. There are two limitations of national instructions and audiences required to be followed in the country, where the research has been conducted, and the lack of data that leads authors to receive help from experts who are dealing with traffic and transport planning in local and national manner. Therefore, the main concept behind this research work is to design pedestrian pathways together with lanes for cars, private cars, or public transport facilities, where the portion of each element is determined by proposing different scenarios. In each scenario, street designing is made by a combination of car traffic lanes and pedestrian paths where the behavior of both segments is simultaneously analyzed by simulation modeling. Public transport planning would also be considered an important issue for defining the scenarios where it may be merged with private cars traffic as well. The concept would help transport planners follow local authorities' concerns when they are dealing with local traffic cars that cannot be banned from crossing the streets. Following the above concept, the research methodology would compose of three main steps including scenario definition where the path is distributed between traffic and pedestrians, designing lane width, analyzing the performance criteria, and eventually comparing the measures to select the best scenario, all discussed in the upcoming sections. The third step is necessary to overcome the second limitation, aforesaid, where the lack of data hampers the authors to evaluate the scenarios using the required data.

3. RESEARCH METHODOLOGY

Several scenarios regarding the walkability and non-walkability of the streets are considered to organize the traffic as well as to achieve sustainable transport. In some scenarios, pedestrians and public transport vehicles are prioritized, and private cars are prohibited to pass. In some others, narrow roadways are considered to complete traffic loops in the designed transportation network. Since delay is one of the most irritating aspects of traffic with adverse mental effects on people due to the loss of time, the delay is also used to evaluate proposed scenarios and select the best. After the simulation process of the current situation and all scenarios, the average delay for each vehicle will be derived. The best scenario is the one with the minimum delay, accordingly.

In terms of attributes, the cost is another parameter affecting the decision and selecting the best scenario because allocated budgets play a major role in the possibility of turning streets into pedestrian zones. The costs include roadway and walkway construction, acquisition, and destruction. Lack of foresight is an essential weak point of urban planning systems. In addition, anticipating the future and limiting uncertainties is a key concern for urban planning. In fact, real-time decision-making is one of the major objectives of urban planning to direct future urban activities toward the citizen benefits. From an urban development perspective, a passage network is a kind of occupancy. The damage or improvement imposed on the urban landscape by building occupancy is a serious concern for urban development engineers. Regarding the historical and tourist attractions in the area under study, the desirability of scenarios in terms of urban development is another factor for determining the optimal scenario. In urban development activities, the destructed area of historical districts and the preservation of historical passages are considered as criteria of comparison. In the process of transport planning and evaluation and decision-making for various options possible for improving the transport situation and traffic, experts typically face multiple objectives and criteria. They use various methods such as multi-criteria evaluation and multi-criteria decision-making to compare options or alternatives based on (and sometimes contradicting) objectives and criteria. The methodology steps are shown in Figure 1. The present research work adopts the analytic hierarchy process (AHP), a well-known and effective decision-making technique, to evaluate and prioritize the proposed scenarios for improving traffic conditions. In the current study, the weights of the scenarios in terms of traffic, cost, and urban development are calculated in the first step. The relative weights of the scenarios belong to the objective are sequentially determined in the second step. For the third step, the final weight of each scenario is eventually calculated by multiplying the weight of each criterion by the weight of the scenario for the corresponding criterion. The mentioned process needs more data that should be gathered in qualitative manners where transport experts rank the rates. Therefore, a questionnaire has been specifically designed for this research work and distributed to be filled out by Kerman transport experts to determine the weight of scenarios.

4. INTRODUCTION OF CASE STUDY

Shahid Fath-Ali Shahi Street in the historic districts of Kerman has been selected as the study area. The street comprises of historic spaces like bazaar, mosque, business centers, etc. The area, road map, and occupancies are shown in Figure 2. The well-known area of Pamanar neighbourhood (Fath-Ali Shahi Street) is located in the historic districts of Kerman. It has potential in terms of building walkways and attracting tourists due to the presence of several cultural and historical monuments and the interconnected network of urban spaces. The forgotten cultural values and preserving the native heritage can be the main motives for people to use the intended pedestrian zones in the area. On the other hand, the narrow passages and crowded streets in rush hours caused by vehicles indicate that turning the street into a pedestrian zone and providing alternative paths around Fath-Ali Shahi Street can reduce traffic volume and congestion as well, so the above neighbourhood is the best place to study.

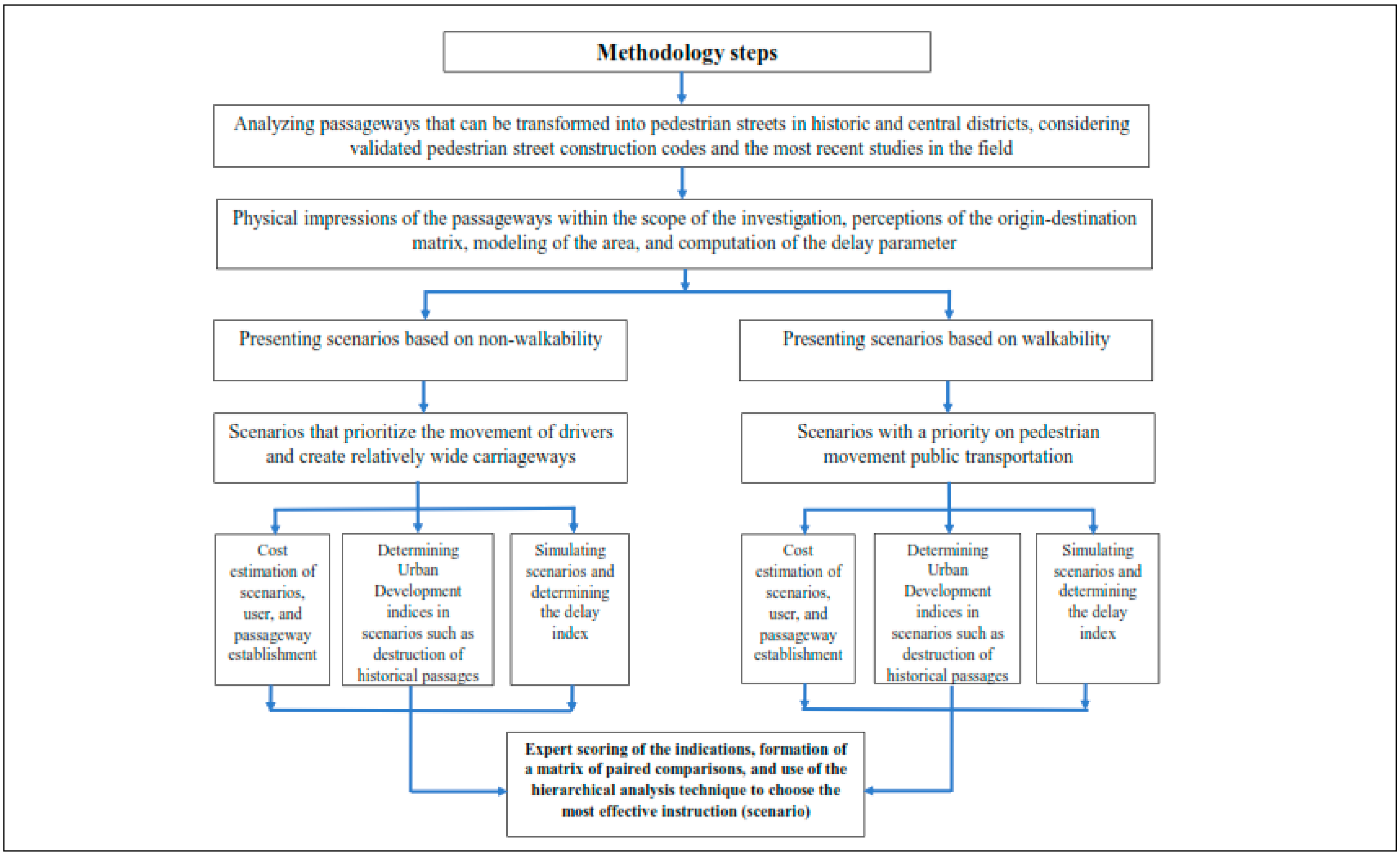

Figure 1. The Research Methodology Steps.

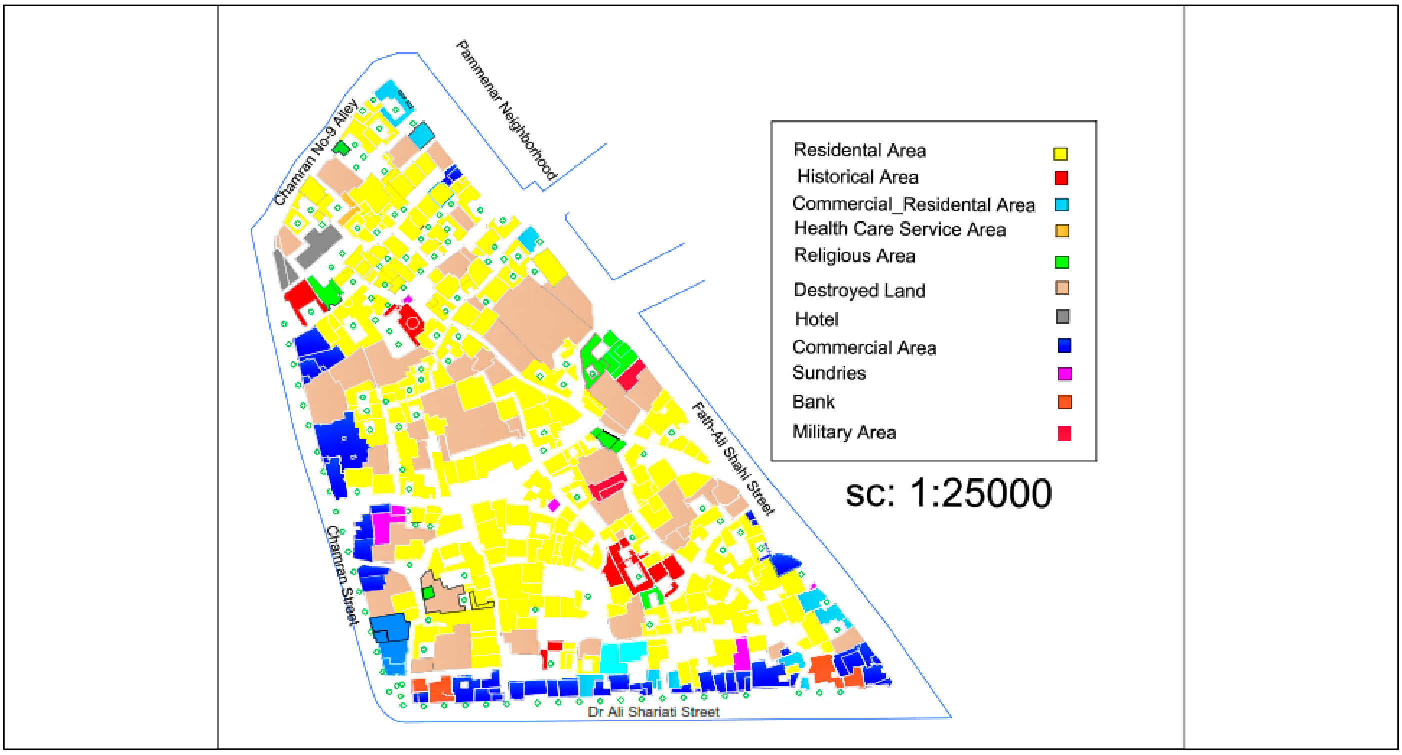

Figure 2. The area under study, road map, and occupancies (Kerman Comprehensive Transportation Plan, 2010).

4.1. Pedestrian Zone Feasibility Steps

Based on the guidelines for walkway and bike path design published by the Washington State Department of Transportation (WSDOT, 2018), the feasibility study of a pedestrian zone needs to perform the five following steps. All steps have been followed to perform the feasibility study.

First Step: Topographical Situation

At the first step, the topographical conditions of the region should be assessed. Routes with a longitudinal slope of more than 5% cannot be used for walkways because pedestrians do not feel comfortable. It should be noted that if the sloped route is less than 200 m, a maximum longitudinal slope of

7% is allowed. Field observations indicated that the longitudinal slope of Fath-Ali Shahi Street is 0.6% suitable for Pedestrianization.

Second Step: Geometry of the Street
The geometric situation of the street should be evaluated. A 3.5 meter-wide roadway must be considered for ambulances, fire extinguishing facilities, and municipality service vehicles. Otherwise, it is not allowed to pedestrianize such streets. Fath-Ali Shahi Street is currently a one-way street with an average width of 15 m where 12 meters is dedicated to the roadway, and the remaining for the walkway.

Third Step: Alternative Path
This step addresses an alternative path. If Fath-Ali Shahi Street becomes a pedestrian zone, Shahid Chamran or Shahid Bahonar Streets can be used as alternatives. The alternatives would be assigned for private cars traffic those may be banned to pass the road assigned for pedestrians according to the study.

Fourth Step: Vehicle Accessibility to Occupancies
Vehicle accessibility to occupancies is evaluated in the fourth step. Since there are various occupancies in the region and Pedestrianization would limit the access of vehicles to those, the accessibility of occupancies adjacent to the pedestrian zone should be evaluated. The filed observations, implemented by authors, revealed that most occupancies surrounding the pedestrian zone were commercial and residential without parking lots. Therefore, walking does not block access to occupancies.

Fifth Step: Providing Proper Parking Space at a Proper Distance
The field observations revealed that the closest parking spaces to Fath-Ali Shahi Street are located in Shahid Chamran or Shahid Bahonar Streets. The above five steps showed that it is possible to pedestrianize Fath-Ali Shahi Street, according to WSDOT guidelines. The cross-sectional of this street is depicted in Figure 3.

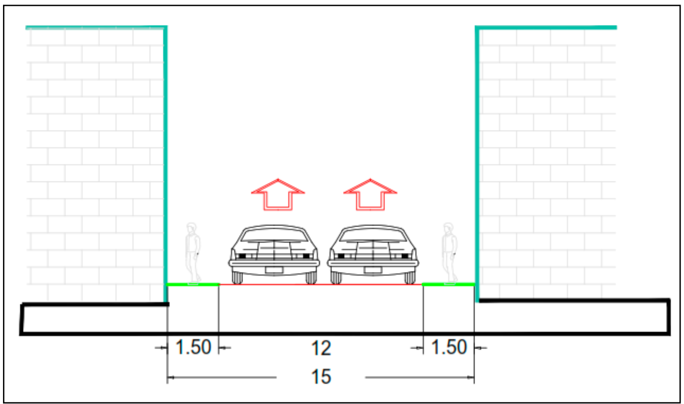

Figure 3. Cross-sectional Fath-Ali Shahi Street.

4.2. Traffic Simulation of the Current Situation

The traffic situation of the studied area is determined based on the driving cars and walking traffic volume. According to overall stats derived from collected data and the specification of the field, the rush hours are around noon and afternoon. Therefore, the data of driving traffic volume was collected for 12:00-14:00 and 17:00-19:00. The delay based on the current traffic situation was calculated as 87.44 s/km using simulation software by adopting the traffic volume data and forming the travel demand matrix. Several scenarios of walk-ability and non-walk-ability have been considered to reduce the delay for vehicles passing through the lanes.

5. SCENARIO DEFINITION

Eight alternatives (scenarios) have been proposed to evaluate the effect of pedestrianizing on Fath-Ali Shahi Street. The idea of each scenario composes of four components including promoting walking conditions, organizing public transportation, improving on-street parking, and enhancing passage capacity, all based on the sustainable transportation criteria. They are tabulated in Table 1.

Idea	Description Each Scenarios
Promoting Walking Conditions	The Pedestrianization of Fath-Ali Shahi historic street
	Making Fath-Ali Shahi historic street walkable
Organizing Public Transportation	Preventing taxis from using special lanes
	Improving headways and system reliability
Improving On-Street Parking	Eliminating impermissible on-street parking
	On-street parking policies based on the street conditions
Enhancing Passage Capacity	Widening Fath-Ali Shahi Street with the least destruction possible
	Widening Fath-Ali Shahi Street with the most destruction possible

Table 1: The ideas used for scenario definition.

A combination of Pedestrianization and public transport development has been considered for improving walk-able scenarios. For scenarios with prioritizing motor vehicles, narrow passages with the minimum street destruction would be constructed in historic districts to facilitate the accessibility of internal areas. In this case, the widening and design would be based on the data analysis provided by studying the geometrical structure of the district and emphasizing urban-scale maps. This kind of intervention is a preliminary design for the plan location concerning the phenomenal and visual existence of landscapes and walls. The design is systematically based on the potential of the location, concentrating on spatial values and environmental potentialities. In other words, by widening the street passages and preserving the national heritage, the widening practice is simultaneously implemented in another direction with the least damage to the invaluable and registered monuments. In this study, some proposed scenarios are implemented on widening of Fath-Ali Shahi passage within the historic district of the region. These scenarios are proposed to evaluate the effect of constructing new passages and nodes on traffic in the area under study, as well as the effect of such passages on better accessibility of internal areas. The scenarios are here explained more in detail.

In scenario 1, Fath-Ali Shahi Street would be a pedestrian zone. This scenario is pedestrian-oriented, so no vehicle is allowed to pass as shown in Figure 4 where the passage for walking and vehicles are also separated.

The ideas behind scenarios 2, 3, and 4 are based on the improvement of the public transportation system (reducing the volume of private cars and transferring passenger demand to public transport). In addition, in order to reduce the delay and travel time of public transportation, the parallel parking on both sides of the street should be limited. In the above-mentioned scenarios, Fath-Ali Shahi Street is regarded as walkable by reducing the roadway width by 9 meters and adding to the sidewalks as shown in Figure 5. On the other hand, through the enhancement of public transport, the driving volume is reduced by 10 (set in figure 4), 20, and 30% for scenarios 2, 3, and 4, respectively.

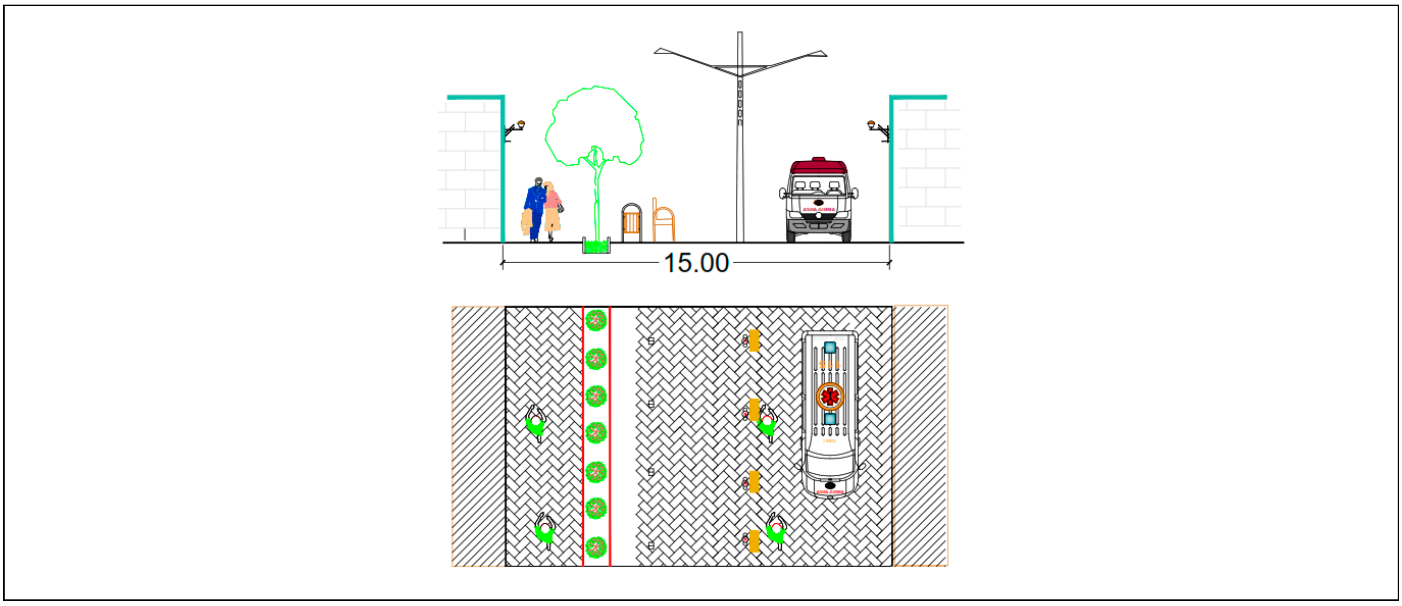

Figure 4. Cross-sectional Fath-Ali Shahi Street in scenario 1.

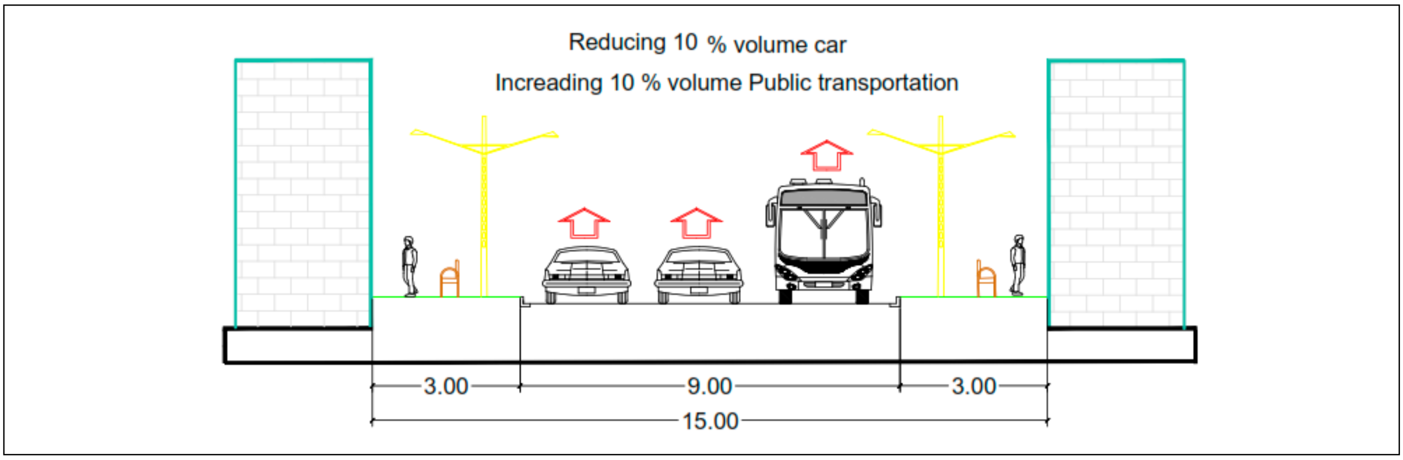

Figure 5. Cross-sectional Fath-Ali Shahi Street in scenarios 2, 3, and 4 where the car volume reduction and promoting rate for public transport are considered respectively as 10 (set in the Figure), 20, and 30 percent.

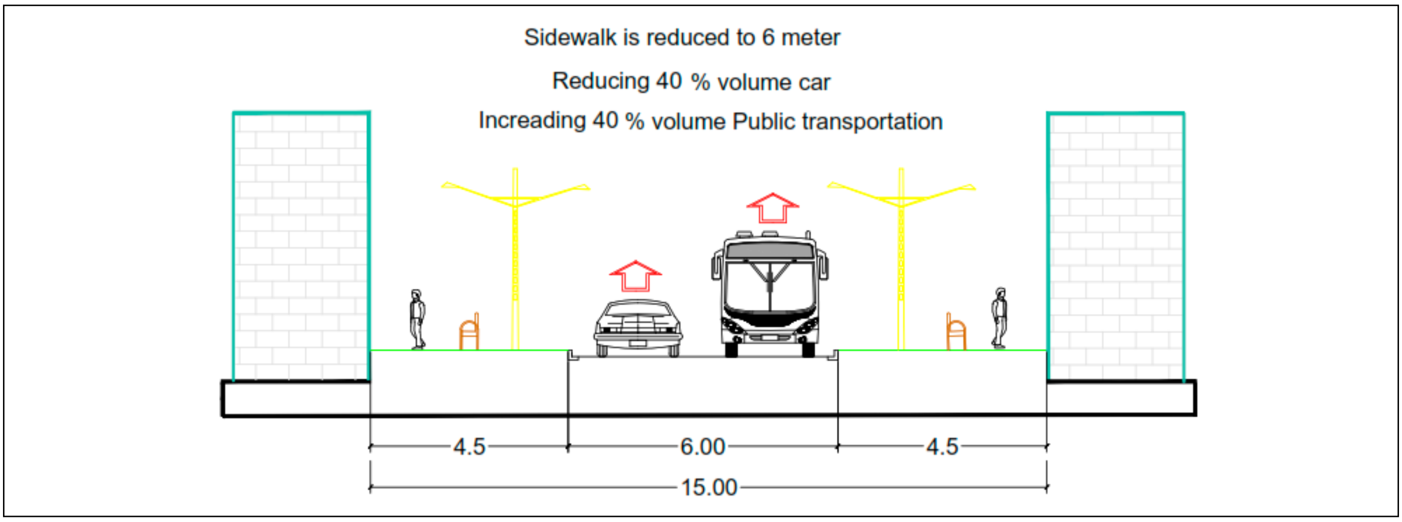

Figure 6. Cross-sectional Fath-Ali Shahi Street in scenario 5 and 6 where the car volume reduction and promoting rate for public transport are considered respectively as 40 (set in the Figure) and 50 percent.

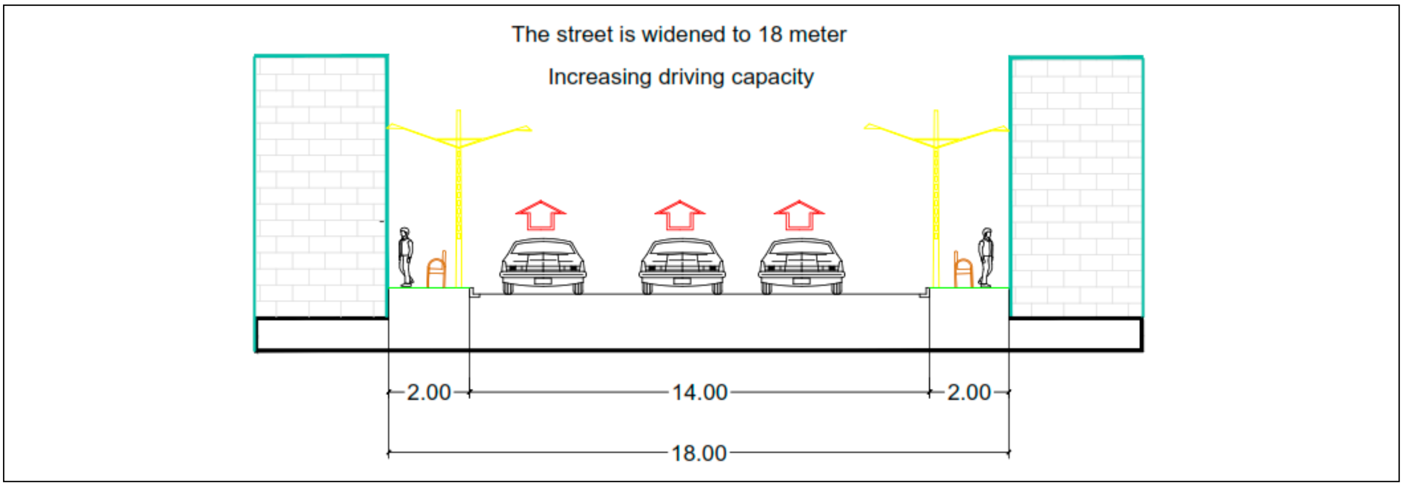

Figure 7. Cross-sectional Fath-Ali Shahi Street in scenario 7.

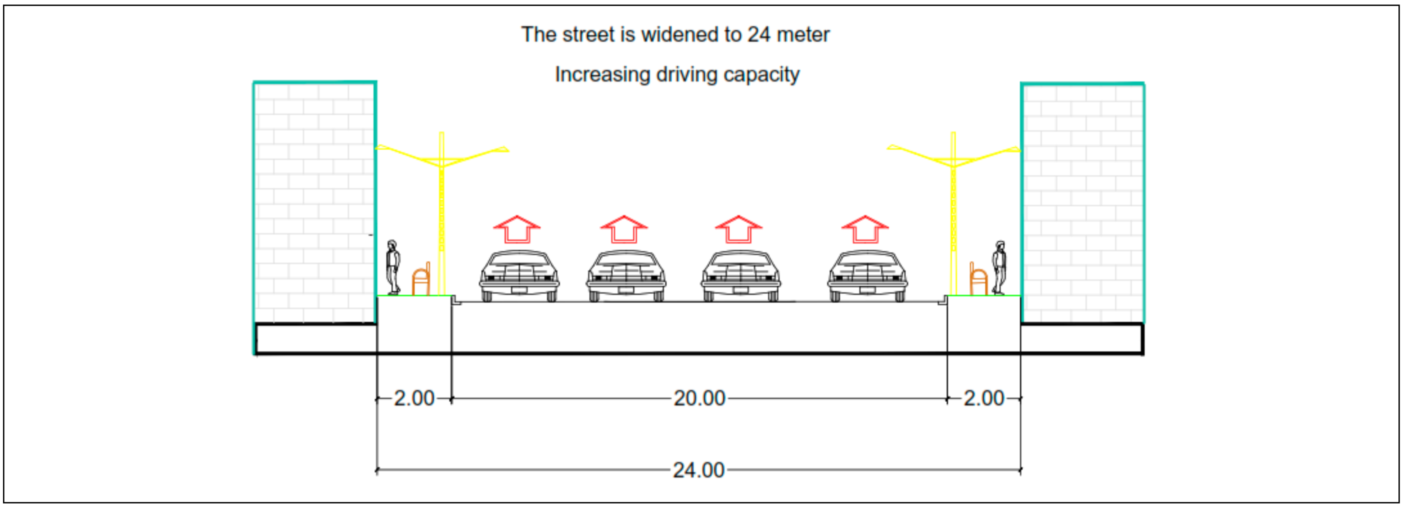

Figure 8. Cross-sectional Fath-Ali Shahi Street in scenario 8.

In scenarios 5 and 6, high priority is given to the public transportation system. The public transportation is assigned to a separate line where the passenger demand of private cars volume is moved to public transportation. Additionally, in the above-mentioned scenarios, the parallel parking spaces on both sides are totally removed. Furthermore, a higher percentage of Fath-Ali Shahi Street is dedicated to sidewalks. The roadway width is reduced to 6 meters while 6 meters of space is merged with the sidewalks. The increased share of public transport led to a 40 (shown in Figure 6) and 50% reduction in driving volume.

The idea taken into account in scenarios 7 and 8 is founded on increasing the supply (increasing the number of private car lanes) and increasing the private car traffic demand (increasing the volume of private cars). For scenarios 7 and 8, Fath-Ali Shahi Street is widened to increase the driving capacity and direct more vehicles to the surrounding main streets. The street is now widened to 18 and 24 meters in scenario 7 (depicted in Figure 7) and scenario 8 (depicted in Figure 8), respectively.

5.1. Scenarios' specifications

5.1.1. Traffic simulation

Simulation is a computer based and useful technique to check the efficiency of proposed modification on the procedures, in particular, on transport infrastructures (Mahmoudabadi, 2014) in which the results of improvements or modifications can be analysed prior to implementation. Since reconstruction and modifications on roads and transport facilities are usually costly and implemented in long-term periods, the above technique is commonly performed to investigate the proposed scenarios prior to making decision. In simulation, the desired output measures are compared and studying the results helps authorities to make the best among or practical proper alternatives. Therefore, each scenario is simulated to calculate the delay in second per kilometre as criterion for comparing scenarios. The delay for each scenario has been obtained and is now reported in the third column of Table 2. Collecting the volumes of pedestrian and vehicular traffic are the basis for understanding the traffic situation and determining traffic parameters for simulation. Hence, according to studies and field visits, the peak hours of traffic in the morning and in the evening were considered respectively at 8:00-9:00 am and at 6:00-7:00 pm. The above traffic volume is counted and the travel demand matrix in the peak hour of the network (6:00-7:00 pm) was created by the simulation software of AIMSUN (Version 6) that is commonly used for traffic simulation in the university, affiliated to the first author, because the software license was available for professional modelling. Other parameters, that we needed to draw the network in the simulation software, represent the width of the and the number of carriageways, public transport lanes, and the allowed directions and turns at each intersection, and the timing of the traffic lights, which these parameters have been collected in the field. Two parameters of average speed and the volume of network lanes were also calculated according to the national codes of constructing urban roads. After drawing the network and entering the traffic parameters and the travel demand matrix in the simulation software and running the simulation models, the output of the traffic parameters is considered for traffic analysis.

5.1.2. Construction cost and the expense incurred to the user

Cost is another critical parameter affecting the decision of the most ideal scenario. The total cost of a scenario includes the Pedestrianization of historical passages, elimination of on-street parking, parking lot construction, organizing public transport system, destruction, acquisition, widening, and construction of passages, and the overall expense committed to the user. Evaluating the effect of the budget could contribute to the improvement of traffic in Shahid Fath-Ali Shahi Street (Pamanar). The expense incurred to the users represented by calculating the value of travel time (VOT). Travel time in the transportation economy is the cost a traveler pays during his/her trip. Either the traveler pays an expense to save time or pays it to compensate for the time lost (Mackie et al, 2003). The value of travel time is positively related to the user's income, as formulated by equation 1.

$$(1) \quad VOT = \frac{Income}{T*8}$$

VOT is the Value of travel time (per hour), Income is the Annual average income of each user (Rial, Iranian currency) and T is the number of workdays. In the following, based on the time of travel (VOT) and the delay for each scenario (column 3 in Table 2) the expense incurred to the user. After that, the construction cost of all the mentioned measures has been calculated. Finally, the total cost of all scenarios including construction cost and the expense incurred to the user is reported in the fourth column of Table 2.

5.1.3. Urban Development

Scenario desirability in terms of urban development is another relevant attribute to select the best scenario. There are certain criteria such as Pedestrianization of historical passages, organizing public transport system, elimination of on-street parking, and compatibility with the general urban plan to determine the desirability of mid-term scenarios in terms of urban development. For long-term scenarios, criteria including the destructed area of historical districts and preservation of historical passages, and compatibility with the general urban plan were used to determine their desirability. All scenarios had 100 points as their baseline for rating. For the destruction of historical districts, endangerment of historical passages, and incompatibility with the general urban plan, each scenario loses some points based on the experts' viewpoint. The area of valuable monuments, which is implemented by widening passage with the least and the most destruction possible (scenarios 7 and 8) is also shown in figure 9, so these scenarios have been taken the lowest score in terms of urban development due to the fact that not compatible with the preservation of historical places. Moreover, the relative weight of scenarios in terms of urban development has been finally listed in the last column of Table 2.

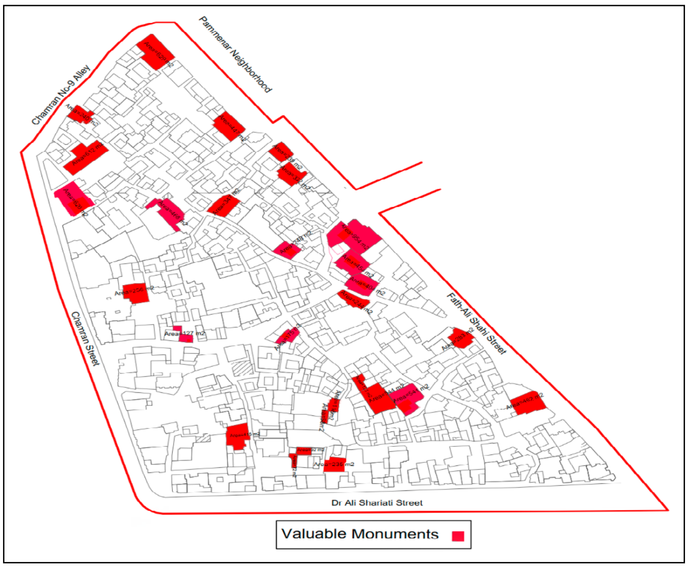

Figure. 9. Area of valuable monuments of the case study (Kerman Comprehensive Transportation Plan, 2010).

6. SUPERPOSITION OF ANALYSIS RESULTS AND SELECTION OF OPTIMAL SCENARIO

To assess and prioritize the suggested scenarios regarding traffic improvement, AHP is used in this paper as one of the most well-known decision-making techniques. By performing AHP method, the preferred judgment aims is used to compare the various scenarios based on each judgment criterion according to the importance of that judgment criterion in

Scenario	Description	Delay Time	Cost	Relative Weight
1	Pedestrianization of Fath-Ali Shahi Street in total width	89.29	12624	100
2	Walkability by reducing the roadway width from 12 m to 9 m (increasing the walkway width), a 10% decrease in driving volume, and an equal increase in public transport	56.12	11427	80
3	Walkability by reducing the roadway width from 12 m to 9 m (increasing the walkway width), a 20% decrease in driving volume, and an equal increase in public transport	34.1	14833	80
4	Walkability by reducing the roadway width from 12 m to 9 m (increasing the walkway width), a 30% decrease in driving volume, and an equal increase in public transport	29.78	17912	80
5	Walkability by reducing the roadway width from 12 m to 6 m (increasing the walkway width), a 40% decrease in driving volume, and an equal increase in public transport	25.1	22457	90
6	Walkability by reducing the roadway width from 12 m to 6 m (increasing the walkway width), a 50% decrease in driving volume, and an equal increase in public transport	23.39	25757	90
7	Passage widening with the least destruction of historic districts from 15 m to 18 m (widening the roadway)	16.25	47068	60
8	Passage widening with the least destruction of historic districts from 15 m to 24 m (widening the roadway)	13.13	63068	40

Table 2: Delay time (Second per KM) derived by simulation process, estimated total cost including construction cost and the expense incurred to the user (Million Iranian Currency), and relative weight of scenarios.

order to determine their weight. The importance or priority of each decision element is determined by comparing them in pair-wise running and assigning a score. Traffic, cost, and urban development criteria were pair-wisely compared in this study. The importance of all criteria and sub-criteria was determined by traffic and transport experts using a designed questionnaire. There are five categories of importance in the questionnaire: very low, low, equal, high, and very high listed in Table 3 where each criterion is tabulated in relation to the others.

Preferential value	The importance of *i* relative to *j*	Description
1	Very low	Criterion *i* is of very little importance compared to criterion *j*
3	Low	Criterion *i* is of little importance compared to criterion *j*
5	Medium	Criterion *i* is of equal importance compared to criterion *j*
7	High	Criterion *i* is of high importance compared to criterion *j*
9	Very High	Criterion *i* is of very high importance compared to criterion *j*

Table 3: Relative importance of all criteria.

This research population is divided into three panels: urban planning, traffic issues, and cost-related issues. For each category, the criteria were subdivided into ten different sub-criteria, and these sub-criteria were completed by experts who were selected through a non-random purposeful sampling procedure. The questionnaire was filled out by 24 experts with bachelor's and master's degrees in transportation planning, economics, and urban planning. There are also experts experienced in project management, transportation, and traffic, and in responsible positions in urban and road development organizations, municipalities, and planning and financial organizations. Seven of the respondents were university professors with doctorates in economics, traffic, and urban planning, while six possessed bachelor's degrees in traffic engineering. Among experts, 50 percent were in the 30-50 years age range, 30 percent were in the 40-50 years range, and 20 percent were older than 50. When more than five comments are included in a hierarchical analysis technique, acceptable results are routinely obtained. However, it was necessary to employ more experts to obtain the desired results in this study. The experts completed 37 questionnaires out of 60 distributed to them. Table 4 shows all the results derived from analysing the filled-out questionnaires. As shown, based on the pair-wise comparison of experts' responses, the weight of traffic, cost, and urban development criteria were determined 0.37, 0.47, and 0.16, respectively.

The consistency rate measure (CR) is used for ensuring the existence of enough consistency between the experts' responses to the questionnaire and pair-wise comparison matrix as well. The consistency rate (CR) is an index that measures the consistency value of experts' responses to evaluation and pair-wise comparisons. A consistency index (CI) is a number used as the consistency criterion to calculate the concordance ratio (CR). The consistency index (CI) was calculated using equation 2 (Kumru and Kumru, 2014).

(2) $CI = \frac{\lambda max - n}{n-1}$

Where:
λmax is the largest eigenvalue resulting from the subtotal of entries of each eigenvector and the subtotal of columns of the reciprocal matrix, n is the number of compared criteria, and CI is corresponding to the random consistency index (RI). Table 5 shows RI for the compared criteria number (n).

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Table 5: Random consistency index for n from 0 to 10.

Equation 3 was used to calculate the consistency rate (CR) between CI and RI.

(3) $CR = \frac{CI}{RI}$

If the consistency rate is less than or equal to 0.1 (CR<=0.1), the pair-wise comparison matrix is compatible. If the compatibility rate is above 0.1 (CR>0.1), it shows a contradiction in experts' evaluation and judgment, and the pair-wise comparison matrix must be re-evaluated so that the rate drops below 0.1. Considering pair-wise comparison matrix (Table 4), resulting from experts' opinions, as well as equations 2 and 3, and considering values obtained in Table 5,

Criterion	Sub-Criterion	A	B	C	D	E	F	G	H	I	J	Weight of Sub-criterion	Weight of Criterion
Urban Development	City Appearance(A)	1	7	1/5	1	1/9	1	9	1	1/9	5	0.101	0.16
	Cultural, historical issues and reduction of historical monuments (B)	1/7	1	5	1/7	1/5	1/3	1/5	1/9	1/5	1/3	0.030	
	Compliance with the plan of the area (C)	5	1/5	1	1/3	1/5	1/3	1/7	1/5	1/7	1/3	0.0302	
Cost	Cost of acquisition and destruction of properties (D)	1	7	3	1	1/9	1	1/9	1/3	1/5	1	0.048	0.47
	Construction cost includes building new pathway (E)	9	5	5	9	1	9	1	3	1/3	3	0.203	
	Cost of public transport development (F)	1	3	3	1	1/9	1	9	3	1	3	0.110	
	Cost of removing parallel parking and building non-parallel parking (G)	1/9	5	7	9	1	1/9	1	3	1	1	0.111	
Traffic	Travel time (H)	1	9	5	3	1/3	1/3	1/3	1	7	1/5	0.123	0.37
	Delay in reaching the destination (I)	9	5	7	5	3	1	1	1/7	1	7	0.178	
	Vehicle stopping time (J)	1/5	3	3	1	1/3	1/3	1	5	1/7	1	0.066	

Table 4: Pair-wise Comparison Matrix.

the following value of consistency index for CR has been obtained as follows:

$\lambda max = 11.11, \quad CI = 0.123, \quad n = 10, \quad CR = 0.083 \leq 0.1$

Since the CR value of 0.083 is less than 0.1, the results of pair-wise comparison matrices from experts' opinions are valid.

Following the above steps, each criterion was employed to calculate the weight of each scenario. The values of criteria for all scenarios determined in previous sections do not share the same dimensions, the ranges and scales are not the same, so the values should be normalized. This is performed by equations (4) and (5) in which $X'_{i,s}$ represents the normalized value of criterion i related to scenario s ($0 \leq X'_i \leq 1$), $X_{i,s}$ represents the value of the criterion i related to scenario s, $X^{max}_{i,s}$ represents the minimum value of criterion i compared to all other scenarios, $X^{min}_{i,s}$ represents the maximum value of criterion i compared to all other scenarios (Xavier Belem et al., 2021). This criterion is normalized by equation (4) since it is a profit criterion. Due to the nature of cost in reverse, equation (5) is applied to traffic and cost criteria. The normalized value list of all criteria, including urban development, construction cost, and traffic, are tabulated in Table 6.

(4) $$x'_{i,s} = \frac{x_{i,s} - x_i^{min}}{x_i^{max} - x_i^{min}}$$

(5) $$x'_{i,s} = \frac{x_i^{max} - x_{i,s}}{x_i^{max} - x_i^{min}}$$

As the criteria weights reflect their importance, and the scenario weights indicate the share of the scenario in the corresponding criteria, the final weight of each scenario is determined by multiplying the weights of the criteria by the scenario weights for the associated criteria, as formulated in equation (6) (Xavier Belem et al., 2021).

(6) $$S_i = \sum_{j=1}^{3} A_{i,j} \times B_j$$

It is essential to multiply the normalized value of each criterion by its weight in each scenario. Each scenario's final weight is determined by the sum of these values known as relative weight. Table 6 shows the relative rank of each scenario based on its relative weight. Subsequently, a pairwise comparison matrix was formed to calculate the weight of each criterion, resulting in 0.37, 0.47, and 0.16 for traffic, cost, and urban development, respectively. For example, the total weight for scenario 1 is calculated as follows:

Total weight for scenario 1:0.37 × 0.036 + 0.47 × 0.193 + 0.16 × 0.161 = 0.130

The total weight for all scenarios is calculated and tabulated as a total in Table 6 formatted in bold.

As shown in Table 6, scenario 2 with the compound weight of 0.142 is the best scenario. In scenario 2, relying on walkability and public transportation by reducing the roadway width from 12 m to 9 m (increasing the walkway width) led to a 10% decrease in driving volume and an equal increase in public transport. This scenario is the most cost-effective one among all scenarios, and it is compatible with the urban development and historic district preservation criteria of Kerman. On the other hand, the scenario paid enough attention to the smooth mobility of motor vehicles and delay reduction in the network.

7. CONCLUSIONS AND RECOMMENDATIONS

In the present research work, according to transport sustainability concepts in which public transport improvement, reduction of private cars' usage, and cutting fossil-fuel consumptions are emphasized, pedestrianization of historic streets is investigated based on three measures of traffic conditions, construction cost, and urban development. The overall concept followed in the present research work is to allocate street lanes to all users including pedestrians, public transport means and private cars while the best measure of traffic planning, minimum delay for all users, obtained. The segmentation based on traffic demands as well as their requirements such as parking spots and designated width for each user has been considered in construction based on local instructions published for road and infrastructure designing. The measures, considered in road designing, have been extracted from the previous studies conducted in the research field. The above concept is applied by defining eight scenarios in which the portion of each user is allocated followed by studying more in terms of transport measures by developing a simulation model. The Iranian city of Kerman has been selected as a case study and the simulation technique has been performed to select the best scenarios of pedestrianization. Based on the results derived from simulation modelling and considering the experts' viewpoints for selecting the best alternative, the second scenario of "Walkability by reducing the roadway width from 12 m to 9 m (increasing the walkway width), a 10% decrease in driving volume, and an equal increase in public transport" has been selected as the best alternative for pedestrianization of historic streets in Kerman. Based on the methodology followed in the present research work, authorities who are dealing with urban planning are recommended to consider all types of users in the scenario definition. The above mentioned concept would support them for implementing the procedure in different cities or streets that may have been constructed following different urban codes. More details of results and summarizing experts' viewpoints noted in questionnaires also resulted in the following recommendations for future research:

1. Delay time is chosen as the main criterion of traffic. So, it is recommended to use other traffic criteria such as travel time and safety or their combinations in future studies.
2. Other criteria and sub-criteria such as pollution and environmental sustainability can be considered for implementing the AHP technique.
3. This study was limited to eight scenarios based on the walkability and non-walkability of the passage. For future studies, more scenarios combined with transport management policies can be also developed.

Scenario	Traffic	Cost	Development	Total	Scenario	Traffic	Cost	Development	Total
1	0.036	0.193	0.161	**0.130**	5	0.128	0.109	0.145	**0.122**
2	0.057	0.213	0.129	**0.142**	6	0.137	0.095	0.145	**0.119**
3	0.094	0.164	0.129	**0.133**	7	0.197	0.052	0.097	**0.113**
4	0.108	0.136	0.129	**0.125**	8	0.243	0.038	0.065	**0.118**

Table 6. The normalized value of criteria and total weight for each scenario.

4. Since pedestrianization studies are important decisions regarding urban management, it is recommended to account for budget limitations and the financial resources required for each scenario.
5. The technical feasibility of the proposed scenarios should be evaluated prior to further investigation. For instance, the destruction of historic districts might be impossible, and thus, scenarios involving such activities might be rejected in the preliminary evaluations.
6. It is possible the results may differ from area to area and expert to expert opinion, so it is recommended to follow the research methodology with more accurate data elements that represent full dimensions of traffic characteristics.

REFERENCES

Carmon, M., Tiesdell, S., Heath, T., Taner, O. (2003). Public Place urban spaces. *Architectural Press.*

Çinar, S., Yilmaz, Ş., Öz, B. (2022). Pedestrians' Crossing Behaviors and Crossing Preferences: A Field Study. *Transactions on Transport Science*, 2.

Domenico, G., Carla, G, G., Margherita, M. (2022). Experimental models of pedestrian flows as support to design new sustainable paths in urban context. *Transportation Research Procedia*, 60, 188-195, ISSN 2352-1465.

EDIP s.r.o. (2008). TP103 Designing residential and pedestrian zones.

Fournier, N. (2021). Hybrid pedestrian and transit priority zoning policies in an urban street network: Evaluating network traffic flow impacts with analytical approximation., Transportation Research Part Policy and Practice., Volume 152, 2021., Pages 254-274, ISSN 0965-8564.

Gonzalez-Urango, H., Pira, M, L., Inturri, G., Ignaccolo, M., García-Melón, M. (2020). Designing walkable streets in congested touristic cities: the case of Cartagena de Indias, Colombia. *Transportation Research Procedia, 45,* 309-316., ISSN 2352-1465.

Gruden, C., OtkoviĆb, I.IŠ., Šraml, M. (2021). Three-Step Performance Assessment of a Pedestrian Crossing Time Prediction Model. *Transactions on Transport Science., 3.*

Iranmanesh, N. (2008). Pedestrianization a Great Necessity in Urban Designing to Create a Sustainable City in Developing Countries., *44th ISOCARP Congress.*

Khaleghi, N. (2018). Assessing the Impacts of Pedestrianization on Historic Urban Landscape of Tehran., *International Journal Architect Eng. Urban Plan.*

Kerman Comprehensive Transportation Plan. (2010). Kerman Municipality Transportation and Traffic Organization.

Kumru, M., Kumru, P.Y. (2014). Analytic hierarchy process application in selecting the made of transport for a logistics company. *Journal of Advanced Transportation, 974-999.*

Mackie, P.J., Wadman, M., Fowkes, A.S., Whelan, G., Nelthorp, J., and Bates, J. (2003). Valuees of travel time savings UK. Institue of Transport Studies, University of Leeds.

Mahmoudabadi, A. (2014). Developing a chaotic-simulation based model for ranking high selected network links in hazardous material transportation. Modelling and Simulation in Engineering, 2014, 14-14.

Miaoyi, L., Jixiang, L., Yifei, L., Longzhu, X., Jiangping, Z. (2021). Revitalizing historic districts: Identifying built environment predictors for street vibrancy based on urban sensor data. *Cities, 117,* 103305, ISSN 0264-2751.

Mofidi, M., KashaniJou, K. (2010). Emergency of Pedestrianization in Tehran: Obstacles and Opportunities, *International Journal of Urban Sustainable Development.*

Murakami, J., Villani, G., Talamini, G. (2021). The capital value of pedestrianization in Asia's commercial cityscape: Evidence from office towers and retail streets. *Transport Policy, 107*, 72-86., ISSN 0967-070X.

Nalmpantis, D, Lampou, S, Naniopoulos, A. (2017). The concept of woonerf zone applied in university campus: The case of the campus of the Aristotle University of Thessaloniki. *Transportation Research Procedia, 24,* 450-458.

Poyani, D., Stead, D. (2015). Sustainable urban transport in developing world: beyond megacities. *Sustainability Journal, 7,* ISSN 2071-1050.

Rezaei, M. (2022). Expanding walkability in Tehran's historic Downtown. Case study: Streets leading to Imam Khomeini Square (Meidan-e Tup-Khana). *International Journal of Architectural Engineering & urban Planning, 32(2).*

Risser, R., Šucha, M. (2020). Start Walking! How to Boost Sustainable Mode Choice—Psychological Measures to Support a Shift from Individual Car Use to More Sustainable Traffic Modes. *Sustainability, 12,* 554.

Risser, R., Šucha, M. (2020). Psychological Perspectives on Walking: Interventions for Achieving Change. *Routledge.*

Said, S, Y., Samadi, Z. (2016). The Evolution of Historic Streetscape in Adapting Modern Demand in Achieving the Quality of Life. *Procedia - Social and Behavioral Sciences, 234,* 488-497., ISSN 1877-0428.

Safizadeh, M. (2016). Fesasibility conversion Kerman's streets to Pedestrian. Case Study: Dr. Shariati Street., First international & third national conference on Architecture and sustainable urban landscape.

Southworth, M. (2005). Designing the walkable city. *Journal of urban planning and development.* Washington State Department of Transportation (WSDOT) (2018). Design Manual Washington.

Šucha, M., Dostal, D., Risser, R. (2017). Pedestrian-driver communication and decision strategies at marked crossings. *Accident analysis & prevention, 102,* 41-50.

Xavier Belem, M. J., Vieira Junior, M., Mummolo, G., Facchini, F. (2021). An AHP-Based Procedure for Model Selection for Eco-Efficiency Assessment. *Sustainability.*

Yoshimura, Y., Kumakoshi, Y., Fan Yi., Milardo, S., Koizumi, H., Santi, P., Arias, J., M., Zheng, S., Ratti, C. (2022). Street pedestrianization in urban districts: Economic impacts in Spanish cities. *Cities, 120*, 103468, ISSN 0264-2751.