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MMLOS-based study of central streets: re-planning Beyhaq St., Sabzevar, Iran

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ABSTRACT: Planners have been seeking new urban solutions to increase the presence of citizens once again without any constraints to ensure a safe urban space and provide equal opportunities for using transportation modes. Multi-modal level of service, used as a tool for analyzing complete streets, facilitates the creation of a fair and equal environment for all users and the enhancements of public safety and security against road accidents. The main purpose of this study is to resolve the problems of urban space allocation of central streets to all users in cities of middle-income countries that lie in historical context. The analysis is based on the multi-modal level of service indicators and is influenced by efficient plans and global policy strengths. In this regard, identifying the characteristics affecting the road network system in the high-income country plans is inspiring for this research. In this paper by probing the case study and identifying the most important criteria affecting the comfort of street users, the proposed planning framework is presented in two stages: strategies and alternatives. The alternatives are presented at 3 levels based on the type of intervention, which is weighted by the AHP method. Then, the best and most practical alternative is selected based on the local criteria fitting the conditions of Sabzevar city with the TOPSIS technique. The results indicate that historical contexts, especially in the core of the cities, require conservative approaches; so, as much as possible, without physical destruction, the existing spaces need to distribute among all urban users in the most optimal way for ease of movement. Therefore, in Beyhaq Street, as a historical street in the center of Sabzevar city, by inspiring the methods of global traffic planning, a contextual format of devising has been presented to improve traffic problems.

KEYWORDS: Complete street, Level of service, Multi-modal level of service, Traffic planning

1. INTRODUCTION

In a broad sense, cities are spheres where human interactions take place and they abound with many opportunities for people from all walks of life. This issue underscores the significant role of inclusive planning and design for cities. Decades of transportation planning focused on reducing vehicular congestion has created roads with little infrastructure to support active mobility. As cities around the world increasingly embrace alternative modes of transport (Ho & Isaacs, 2018, p.1). The challenge is to address the street as an urban place as well as a movement network and to make this conception of the street not just as an isolated architectural set-piece, but as a part of a wider urban structure (Marshall 2005, p.15). Complete Streets is an emerging urban planning paradigm that strives to balance the needs of pedestrians and bicyclists with those of automobile drivers and transit users. A streetscape designed according to Complete Streets (Ranahan et al. 2014, p.1), not only define alternative modes of transportation but also ensure environmental sustainability and improved economy for cities. Ultimately, complete streets have a strong normative element in that they seek to achieve better urban outcomes. "Better" in the Complete Streets context typically means that roads and immediate surroundings will be safer, more inclusive for a diverse population and range of mode types, and conducive to greater overall vitality. So an increasing number of state and local municipalities around the countries are adopting policies to build streets to accommodate all of the users of the transportation system (Ferguson, 2015, p. 7; Shapard 2013, p.135). One of the tools used for measuring the completeness of streets is the MMLOS[1] which classifies users into categories. Moreover, it takes into account the factors that increase the users' levels of safety, comfort, and convenience while measuring the characteristics of the streets. A majority of streets in Iran are car-oriented due to the dominance of traditional planning, thus prioritizing automobile drivers over others. The main purpose of this article is to identify global transportation-oriented policies to facilitate traffic for users in cities (especially the central streets) and adapt these indicators to the factors of the urban context (as a multidimensional process) and localization of components, being proportional with the LOS[2] required in Iranian cities. To achieve this goal, the present study seeks to explore how lessons from successful global policies can be implemented as local programs in middle-income countries. Thus, the issues and problems of Beyhaq Street in Iran (as an east-west axis in the city center of middle-income country) and the performance of Laurier Street in Canada (as an east-west axis in the city center of high-income country) have first been identified at the four levels of service (pedestrians, bikers, public transportation users, and vehicle users) based on MMLOS, and Beyhaq Street has been planned and redesigned after the policies implemented in Laurier Street were identified (as the redesign framework of Beyhaq Street).

2. LITERATURE REVIEW

2.1 Complete Streets

Complete streets refer to those streets that meet the needs of all users through a fair allocation of street spaces. Complete streets are capable of creating safe public environments that comprise all users of all ages, genders, and physical condi-

1 Multi-Modal Level of Service

2 level of services

tions. These types of streets also ensure efficient mobility by focusing on the people's daily trips, safety, accessibility, vitality, sensitivity to historical context, and environmental sustainability (ITDP, 2019). Complete streets provide a positive physical environment that supports a form of development of the adjacent street which has been already planned (WSP Canada, 2018). To ensure cost effectiveness, the municipality of Tacoma, Washington, U.S. in the mid-1990s, in collaboration with other government organizations proposed constructing more sidewalks and bicycle routes adjacent to traffic (vehicle) routes. This policy then spreads throughout the US and other countries around the world.

2.2 Multimodal Level of Service

LOS (also called quality of service, quality level, or service level) refers to the speed, convenience, travel time, comfort, and safety of transportation facilities and services. It is an indicator that perceived degree of satisfaction with the traveling experience provided by the urban street under prevailing demand and operation conditions. Level of service rankings usually range from A (best) to F (worst) and are widely used in transportation planning to assess potential problems and solutions (AASHTO, 2011, p.121). The multimodal level of service includes a set of discrete quantitative measures used for describing the comfort and convenience of all road users over particular roadways segments or at particular intersections. Multi-modal level-of-service indicators are rating systems used for evaluating different modes of transport and examining their effects (IBI Group, 2015; VTPI, 2019). This method is designed to evaluate complete streets, context-sensitive design options, and smart growth in terms of all street users. The MMLOS method estimates the auto, bus, bicycle, and pedestrian level of service on an urban street using a combination of readily available data and data normally gathered by an agency to assess auto and transit level of service. The data requirements of the MMLOS method include geometric cross-section, signal timing, the posted speed limit, bus headways, traffic volumes, transit patronage, and pedestrian facilities (Dowling & et al., 2008). All four LOS models measure quality of service through a combination of capacity and demand, and a user-perception index, which is calculated with the use of design features and various factors identified through empirical research. The MMLOS method provides an effective way to compare capacity for different modes (Kingsbury & et.al, 2011, p.104) This is constitutes a complex system in that diverse mode options which involved difers in various ways, including availability, speed, cost, density, and the most appropriate use (Liao & et al. 2020, p.250). Highway Capacity Manual (HCM), in 1950, presents an indirect review of the conducted studies on the reduction of vehicle capacities as well as the effects of pedestrians on the mentioned capacities. Later in 1965, the concept of service level was defined in detail and a short chapter was dedicated to the issue of transit. Given the diverse needs of users, in 1985, topics related to walking and cycling were added to this guidebook. In 2000, the components of this guidebook were examined in detail so that in the Pedestrian Chapter, service criteria such as the space for each pedestrian, average pedestrian crossing delay, and average travel speed were studied. In addition, in the Bicycle Chapter, several relevant issues such as average speed and physical barriers were meticulously discussed. In the same year, the Transit Chapter elaborated on four criteria related to passengers such as transit headlines, number of passengers, service hours, and reliability. The 2010 edition of the Highway Capacity Manual assesses four modes of transportation such as vehicles, transits, pedestrians, and bicycles and examines whether or not the existing designs were compatible with all modes of transportation. The findings of the studies in this year showed that not all organizations needed multifaceted survey results and that many bike routes and sidewalks do not require improvement through these multimodal assessments. However, in 2010, the main approach to the multimodal assessment of urban spaces was taken into account (Kittelson Associate, 2012).

2.2.1 Features and Objectives of the Multi Modal Level of Service

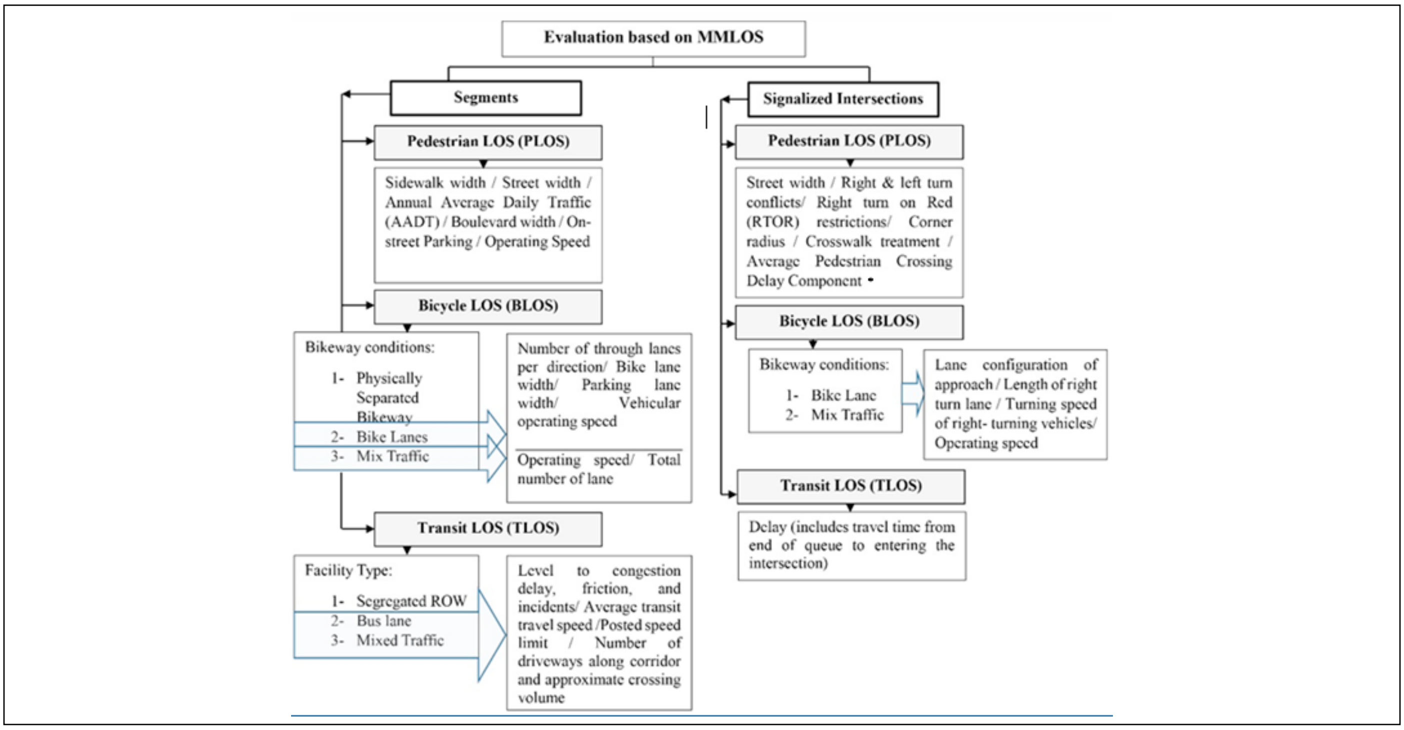
The main objective of the development of multi-modal level of service is to help designers, city experts, and managers evaluate and find the most efficient transportation solution. The structure of the multimodal service of level remains incomplete and flawed until the tools used in it are employed in relation to each other. It should be noted that different streets and roads with similar land use offer different levels of services. Achieving the level of service A is neither possible nor desirable for all modes of transportation on each street due to the limited land resources and budget (IBI Group, 2015). In fact, the multimodal level of service is employed to assess user perception of the existing conditions and review design principles to create equal opportunities for street users by dividing them into four main categories: pedestrians, cyclists, transit users, and vehicle drivers. A considerable deal of attention should be given to this type of analysis tool used in planning to achieve a complete street pattern so that the services required by different users would be identified, hence the improvement of the quality of the environment and increase in users' presence. A brief review of urban planning based on the multi-modal level-of-service analysis enjoys several advantages, namely some facilities on streets such as special routes for cyclists, appropriate width of sidewalks, islands and shelters suitable for pedestrians and cyclists, traffic control of vehicles, special routes for transit, pedestrian-friendly flooring and signs, and standard traffic signs and rulers. Multi-modal level of service standards can be applied to support internal development and smart growth by reducing the level of vehicle services, which can be achieved only when the service level for other modes of transportation is improved and the development costs are dedicated to the enhancement of public transportation and non-motorized vehicles instead of further development of highways (VTPI, 2019). We briefly discuss how street re-plan options are based on these functions, and we illustrate some of their alternative implementations in Beyhaq Street of Sabzevar.

3. MATERIALS AND METHODS

To reach mentioned aim, the most basic and important action is attempting to identify the weaknesses, issues, and problems of Beyhaq Street based on MMLOS analyzes and employing constructive policies to improve its condition by extracting implemented policies in the Laurier street area and using these policies to provide indigenous options for Beyhaq Street.

The reason for choosing Laurier Street is the method that IBI group have conducted in the MMLOS Guidelines on the city of Ottawa which is used for this research. Based on IBI group studies, Laurier Street is a successful example of providing proper services to cyclists. In order to complete the study process, in this research, we have expanded the studies related to Laurier Street in the pedestrian and public transportation LOS (refer to the studies in the appendix); and finally, Beyhaq Street is re-planned and redesigned with Laurier Street comprehensive policies in order to achieve equal quality of service for all street users.

The importance of this research is to identify real functions of the streets that were designed according to novel planning



*Average pedestrian crossing delay = $0.5 \times \frac{(\text{cycle lenght} - \text{Pedestrian effective walk time})^2}{\text{cycle lenght}}$

Figure 1: Flowchart: Evaluation based on MMLOS effective components

so that the reflection and implementation of the extracted functions could help improve the performance of communication systems in middle-income countries considering local contexts in both site.

Beyhaq Street, a historic and traditional street located at the city center, is always one of the most crowded streets in Sabzevar, Iran and it is subject to traffic congestion during peak hours that negatively affects environmental quality and social justice in the city. This street is distinguished from others since it functions as a joint, connecting the main streets of the region including Kashefi, Asrar, Atamalek, and Amir Massoud, thus undergoing a heavy traffic every day.

In this regard, a careful study of this street and the corresponding equal spatial planning can affect the traffic relations of the entire urban network, ultimately leading to the realization of social justice. Therefore, this study uses a combination of qualitative and quantitative methods to meet its practical purpose based on the proposed objectives. The novelty of the present study lies in the analysis of MMLOS indicators for different street segments and the signalized intersections of this street to determine a complete street structure.

Relevant data were collected through library documents and field observations. To be more specific, in the section on library documents, the required data (traffic volume, average speed of personal vehicles, effective speed of pedestrians, etc.) were collected from relevant organizations (municipalities and the Transport and Traffic Organization, etc.) to carefully study the related theories and review the historical records. In addition, in the field observation, the geometric parameters of Beyhaq Street were examined and the movement behaviors of users were identified.

The data analysis was performed by investigating the current situation of Beyhaq Street based on the indicators and standards of the MMLOS. To this end, first, the current services accessible to street users (except truck drivers because trucks are not allowed on this street) on Beyhaq Street were analyzed and then according to the level of service standards in Ottawa, Canada, 16 effective indicators in Iranian indigenous planning were extracted. It should be noted that the overall design structure and framework have been influenced by the Ottawa policies, and in designing the details, local conditions have been taken into account. These 16 components are the intersection of global and local policies which are taken from Laurier street performance but in detail of redesigning are following up the urban context. Based on the extracted criteria, three levels of solutions with different interventions were presented and prioritized as follows: First, these 16 extracted indicators were weighed by AHP[3] method to determine their effectiveness.

Upon weighing each indicator, the TOPSIS[4] method is employed to examine how each of the planned options would respond to the MMLOS criteria.

3.1 Case Study

In the present study, Beyhaq Street in Sabzevar, Iran was considered as the case study to investigate, analyze, and plan the MMLOS indicators and achieve a complete street pattern. The research process comprises identification, assessment of the current situation, draw inspiration from the strength of global programs (Laurier street in Ottawa) in addressing the threats to and weaknesses associated with various street users (pedestrians, cyclists, public transport, and personal vehicles) in the existing plans of Beyhaq Street, presentation of operations and solutions, and evaluation of solutions.

Beyhaq Street located at the city center, a historic district, hosts many daily traffic, hence heavy traffic on this street (Figure 2). It, situated between Si-Hezar Metri square and Kargar Square, is about 2 kilometers long with a width of 22-23 meters and as an east-west axis, it is the main intersection of four north-south axes including Kashefi, Asrar, Atamalek, and Amir Massoud Streets and also, is the minor intersection between Ghaem Street and Hakim Street (Figure 3).

3 Analytic Hierarchy Process
4 Technique for Order Preference by Similarity to Ideal Solution

Due to its significant location, this street encompasses a variety of land uses ranging from commercial and administrative to historical and religious uses, thus increasing the traffic load on this street (Figure 4).

Beyhaq Street was investigated through the analyses of MMLOS by dividing it into six segments and three signalized intersections (Figure 5).

In this regard, the distance from Si-Hezar Metri square to Amir Massoud Street is considered as Segment 1, Amir Massoud Street to Atamalek as Segment 2, Atamalek to Asrar as Segment 3, Asrar to Ghaem Street as Segment 4, Ghaem Street To Kashefi Street as Segment 5, and Kashefi Street to Kargar Square as Segment 6. Analysis of the level of services for vehicles on Beyhaq Street based on the ratio of volume to road capacity, which capacity calculated according to the Road Design Manual (Deputy Minister of Transportation, 2020) and volume recorded based on field visits (between 11:30 A.M to 1:30 P.M), demonstrates that vehicle traffic from Segment 1 to the eastern part of the city is in its worse condition (Table 1).

These segments were investigated in their current situation and then, solutions were suggested based on the MMLOS indicators.

The analyses of the situation of Beyhaq Street were separately done in terms of the segments and the signalized intersections with emphasis on four main users: pedestrians, cyclists, transit users, and car drivers.

Note that these segments were selected based on the differences and changes in the transportation systems.

A study of the current situation of Beyhaq Street is presented, which shows the policies adopted for each of the users in city of middle-income country (Tables 2).

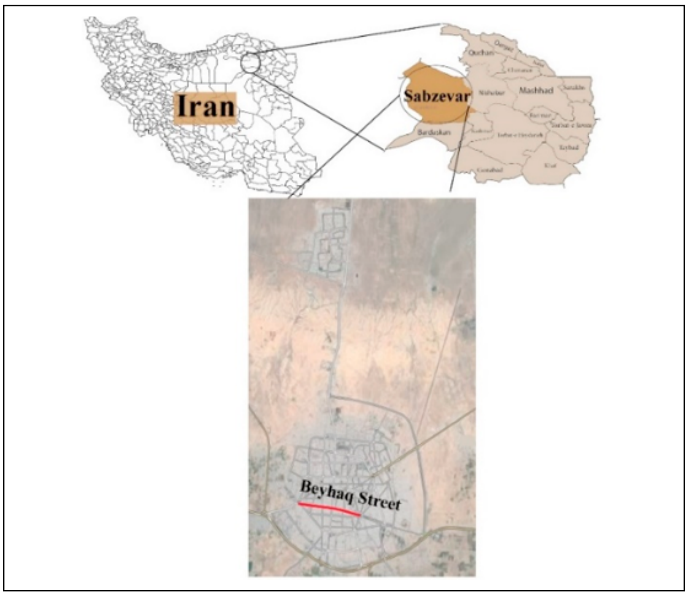


Figure 2. Case study situation (Google map)

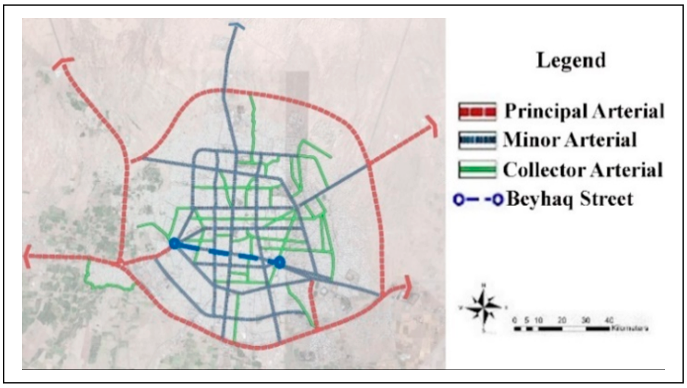


Figure 3. Urban road hierarchy of Sabzevar (PCE, 2015)

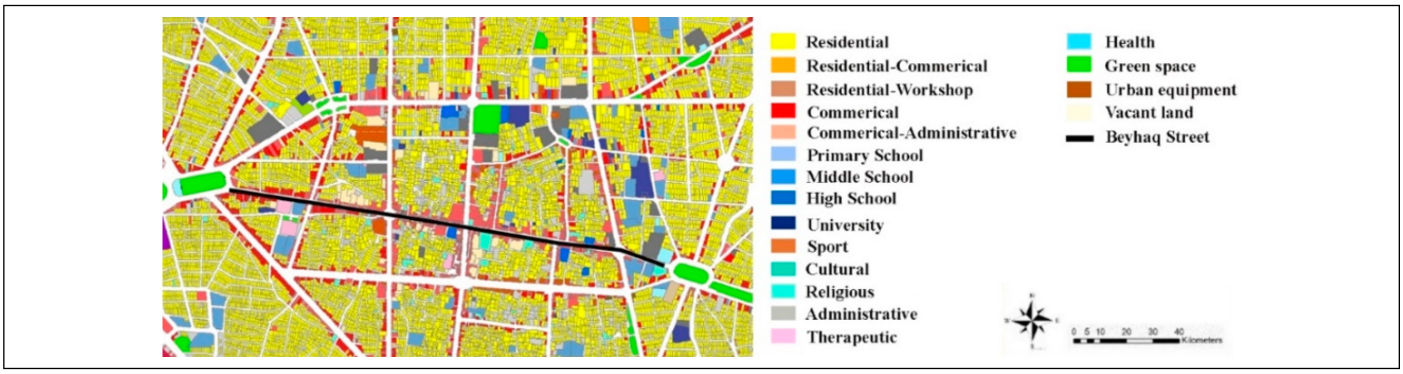


Figure 4. Land uses adjacent to the case study (PCE, 2015)

Segments	Segment 1		Segment 2		Segment 3		Segment 4		Segment 5		Segment 6	
	East to West	West to East	East to West	West to East	East to West	West to East	East to West	West to East	East to West	West to East	East to West	West to East
Capacity	896	896	896	896	896	896	-	833	-	833	588	588
Volume	597	654	644	665	817	725	-	1300	-	1400	470	580

Table 1: Vehicle LOS of Beyhaq Street

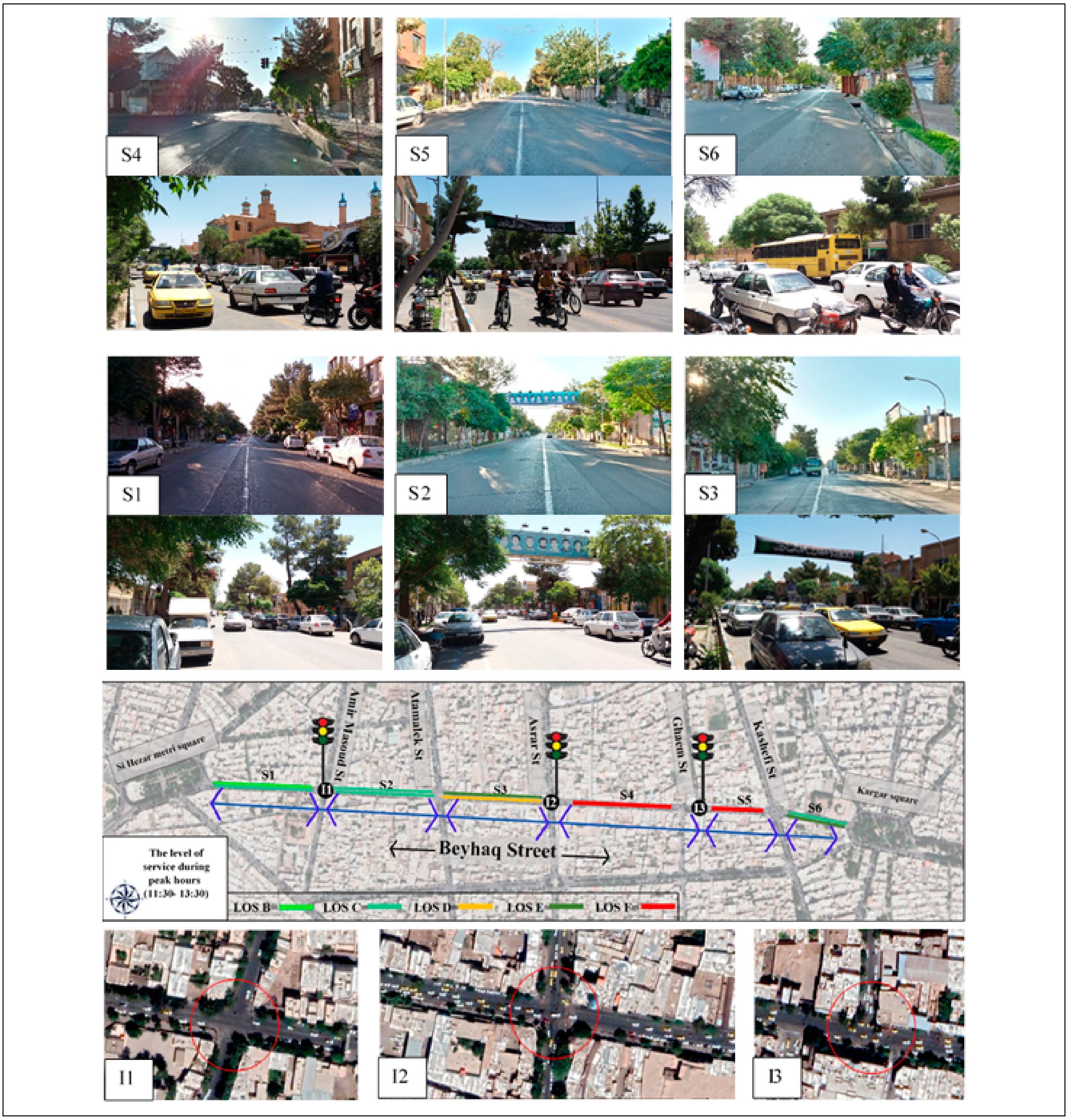
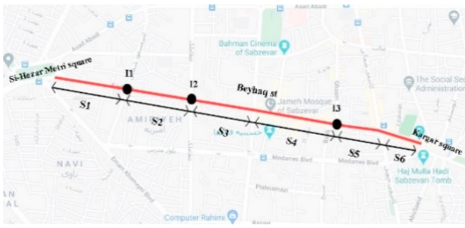


Figure 5: Segments and Signalized Intersections of Beyhaq Street

Table 2. Assessment of Beyhaq Street current situation, by MMLOS Index (the authors)

Location			Beyhaq Street (in middle-income country)					
Functions			Historical and business district					
Sections: East to West (Center Town)								
Segments			**S1**	**S2**	**S3**	**S4**	**S5**	**S6**
Street width (m)			23	23	22	22	22	22
segments	PLOS	Sidewalk width (m)	3.9-3.8	3.5-3.8	3.5-3.4	3	3	3.4
		Boulevard width (m)	0	0	0	0	0	0
		Annual Average Daily Traffic	‹3000	‹3000	‹3000	‹3000	‹3000	‹3000
		On-street Parking	yes	yes	yes	Yes	yes	yes
		Operating Speed (km/h)	Average 50 (km/h)	Average 40 (km/h)	Average 40 (km/h)	Average 40 (km/h)	Average 40 (km/h)	Average 50 (km/h)
	Final score		B	B	B	B	B	B
	BLOS	Physically Separated Bikeway						
		Mixed Traffic	×	×	×	×	×	×
	Final score		D	B	B	B	B	D
	TLOS	Ratio of average transit travel speed to posted speed limit	0.75	0.75	0.62	0.62	0.62	0.62
		Level/exposure to congestion delay, friction, and incidents	low friction due to on- street parking and bystreet	low friction due to on- street parking and bystreet	low friction due to on- street parking and bystreet	low friction due to on- street parking and bystreet	low friction due to on- street parking and bystreet	low friction due to on- street parking and bystreet
	Final score		D	D	D	D	D	D
Vehicle LOS		East to west	B	C	E	-	-	C
		West to east	C	C	D	F	F	E

Signalized Intersections			Signalized Intersections		I1	I2	I3
Signalized Intersections	PLOS		Crossing Distance & Conditions				
			Middle island	North	No	No	No
				South	No	No	-
				East	No	No	No
				West	No	No	No
			Total number of crossing lanes	North	2 lanes with no median (120)	2 lanes with no median (120)	2 lanes with no median (120)
				South	2 lanes with no median (120)	2 lanes with no median (120)	-
				East	2 lanes with no median (120)	3 lanes with no median (105)	3 lanes with no median (105)
				West	2 lanes with no median (120)	2 lanes with no median (120)	3 lanes with no median (105)
			Refuge island	North	No (-4)	No (-4)	No (-4)
				South	No (-4)	No (-4)	No (-4)
				East	No (-4)	No (-4)	No (-4)
				West	No (-4)	No (-4)	No (-4)
			Timing and staging of signs and traffic lights				
			Turning left	North	Protected=0	Protected=0	Protected=0
				South	Protected=0	Protected=0	-
				East	Protected=0	Protected=0	No left turn/prohibited= 0
				West	Protected=0	Protected=0	No left turn/prohibited= 0
			Turning right	North	Protected/permissive = -5	Protected/permissive = -5	No right turn= 0
				South	Protected/permissive = -5	Protected/permissive = -5	No right turn= 0
				East	Protected/permissive = -5	No right turn= 0	No right turn= 0
				West	Protected/permissive = -5	Protected/permissive = -5	No right turn= 0
			Right turns on red	North	allowed= -3	allowed= -3	Prohibited = 0
				South	allowed= -3	allowed= -3	-
				East	allowed= -3	Prohibited = 0	-
				West	allowed= -3	allowed= -3	-
			Pedestrian traffic signals	North	No = -2	Yes = 0	No = -2
				South	No = -2	Yes = 0	-
				East	No = -2	Yes = 0	No = -2
				West	No = -2	Yes = 0	No = -2
			Corner Radius				
			Corner Radius (> 5m to 10m = -5) (> 3m to 5m = -4) (Less than/equal to 3m = -3) (No right turn = 0)	North	-4	-4	-5
				South	-4	-3	-
				East	-4	0	-
				West	-4	-5	-
			Crosswalk Treatment				
			(Textured/colored pavement = -4)	North	-4	-4	-4
				South	-4	-4	-
				East	-4	-4	-4
				West	-4	-4	-4
			Score sum	North	98	100	105
				South	98	101	-
				East	98	97	95
				West	98	99	95
			Final score	North	A	A	A
				South	A	A	-
				East	A	A	A
				West	A	A	A
			Time taken for pedestrians to cross the street				
			Average pedestrian Delay		>20 to 30 sec	>20 to 30 sec	>20 to 30 sec
			Final score		c	c	c
	BLOS		Physically Separated Bikeway		-	-	-
		Mixed Traffic	Right-turn Lane and Turning Speed of M otorists		Right-turn lane 25 to 50 m long, turning speed ≤ 25 km/h (based on curb radii and angle of intersection)	Right-turn lane 25 to 50 m long, turning speed ≤ 25 km/h (based on curb radii and angle of intersection)	Right-turn lane 25 to 50 m long, turning speed ≤ 25 km/h (based on curb radii and angle of intersection)
			Cyclist Making a Left-turn and Operating Speed of Motorists		D	D	D
			Final score		No lane crossed, ≤ 50 km/h	No lane crossed, ≤ 50 km/h	No lane crossed, ≤ 50 km/h
	TLOS		Delay		B	B	B
			Final score		D	D	D

4. DISCUSSION

The most significant shortcoming attributed to Beyhaq St. in Sabzevar is mixed traffic in which all street users are allowed to move around here regardless of the street capacity. The clear problems attributable to this street, as the central route, are the flow of private and public automobiles on shared routes, lack of specific cycling routes, and presence of awkward bus stations all along the street. Given that Beyhaq Street is located in the organic and hierarchical network of the city, heavy traffic volume in peak hours usually causes slow movement and high friction among the users.

However, Laurier Street in Ottawa city is designed based on two objectives of reducing overcrowding and expanding street capacity to meet concentrated demands. In addition, given its graticular texture, Laurier Street distributes heavy traffic in different regions equally and, as a complete street, enjoys the luxury of having different defined spaces for the commute and movement of every street user. According to the findings and data on Laurier street conditions, we found that prohibition of the flow of heavy vehicles and public transportation is one of the reasons for light traffic on this street, while public transportation on Beyhaq street is taking place every day alongside the flow of other street users like cyclists, pedestrians, and private cars without any specific user-defined route, all flowing in mixed traffic and causing inevitable jam quite often. Another shortcoming in city center planning is the free bidirectional traffic on Beyhaq St.; another problem that adds fuel to the fire is the free bidirectional traffic flow on neighboring north-south streets that intersect with Beyhaq St., leading to heavier traffic at the city center, while every other streets that intersect with Laurier street are unidirectional, ensuring orderly and consistent flow of traffic.

It should be considered that management differences concerning the traffic on Beyhaq St. and Laurier St. are rooted in structural, historical, and regional differences of the two countries. Both of the streets are facing various challenges nowadays; however, many of the lingering challenges for Laurier St. were resolved upon readjusting traffic policies and defining routes specific to every user including the cyclists as well as restricting public transportation flow. It's obvious that use of colorful textures on the street surface would elevate its attraction and beauty.

Based on the mentioned policies and by drawing inspiration from Laurier St. conditions, it is recommended that unidirectional traffic movement be considered for the central part of Beyhaq St. and other access points on the neighboring streets be used to alleviate traffic congestion.

Finally, Table 3 lists the most significant identified factors that affect the LOS for each user as well as the main problems observed on Beyhaq Street. These components were employed to offer effective solutions for improving the environmental quality of Beyhaq Street.

The proposed solutions of re-planning in this study were given at two levels: 'Strategies' (suggested executive policies) and 'three alternatives'. Strategies are shared with any of the optional alternative.

4.1 Suggested Strategies

The strategies held in common with all presented alternatives are given below.

4.1.1 Elimination of the On-Street Parking

Given the traffic and spatial divisions of Beyhaq Street, two on-street parking lanes in Segments 1, 2, 3, and 6 were constructed mainly because of the two-way traffic flow. However, there is only one on-street parking lot in Segments 4 and 5 and it is a one-way west-to-east street. With emphasis on the information available on the current situation and the direct impact of traffic flow on the comfort of other users, it can be concluded that on-street parking lots should be eliminated from the street, especially in cases where temporary vehicle stops could possibly increase traffic jams and disruptions. To this end, on-street parking lots should be eliminated in Segment 2 from west to east (with the LOS C), Segment 3 from east to west (with the LOS E), and Segment 6 from west to east (with the LOS E).

The current situation is maintained in Segments 4 and 5 since the street has a parking lot on the one side only and the above holds in Segment 1 due to its proximity to the Si-Hezar Metri square with transit role. The following detailed solutions will be discussed considering the size and dimensions of the driving lanes allocated to all street users.

Pedestrian LOS		Bicycle LOS		Transit LOS		Vehicle LOS	
Existing problems	Effective factors to solve the problems	Existing problems	Effective factors to solve the problems	Existing problems	Effective factors to solve the problems	Existing problems	Effective factors to solve the problems
-No traffic light for pedestrians -Restricted movement for turning right at the intersection -low-quality markings on the surface and pedestrian-pavement -No middle island on different street segments -motorcycles parking on sidewalks and blockade	-Operation speed -Sidewalk width -Boulevard Width -Pedestrian green time (walk time) -Total travel lanes crossed -Signs and road lights -Turning radius -Motor Vehicle Traffic Volume	-mixed traffic -heavy traffic load -no defined position for cyclists at intersections	-Special cycling route -width of cycling route -monitoring vehicle movement at intersections -less obstacles on cycling routes -vehicle speed reduction -Turning radius at intersections	-Shared route with vehicles -existence of minor forks to alleys and nearby stops (Caravanserai) - Stops along the streets	- Speed of traffic flows in the public transportation route -defining a specific route, if possible. - less road obstacle -less inter-state stops -attending to equipment and utilities of users at stops	-Traffic congestion in Segments 4 & 5 -Mixture of different transportation users and thus, more delays in arrival	- Removal of on-street parking lots and defining P+R -reducing width of the lanes (diet roads)

Table 3. Effective factors and existing problems determined by MMLOS for Beyhaq St. (The authors)

4.1.2 Prediction of the Park and Ride Facilities by Eliminating On-Street Parking

Given that eliminating on-street parking from the streets has already been suggested, the necessity of providing suitable places for car parking comes to fore for efficient design and planning. Therefore, due to the high volume of traffic at the city centre, designing parking lots on the adjacent edge of Beyhaq Street and central segments would be absolutely inefficient, thus providing the ground for heavier traffic and further problems. Therefore, this study proposes park and ride facilities outside the urban area by eliminating on-street parking from Beyhaq Street (Figure 6).

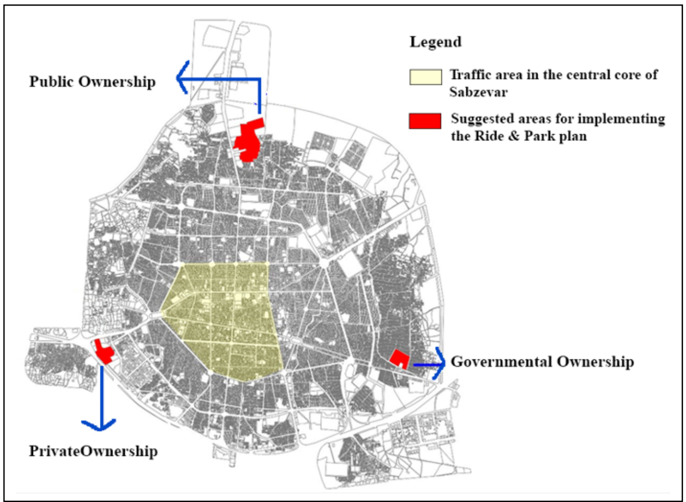


Figure 6. Prediction of the Park and Ride (The authors)

4.1.3 Provision of Cycling Loop System

There is no bicycle lane in the current situation. To resolve the issue, considering the crowded and busy routes and also the land use map, this study suggests a special loop for cycling beyond the area under study, thus justifying the proposed solutions, i.e., allocating a special lane to cycling on Beyhaq Street. The total length of this bicycle loop in the centre is 6865 meters, which finally ends up in Tohidshahr cycling route and the Silk Road (Figure 7).

4.2 Alternatives

Detailed solutions are the alternatives that have been prioritized by TOPSIS technique for three-level planning purposes.

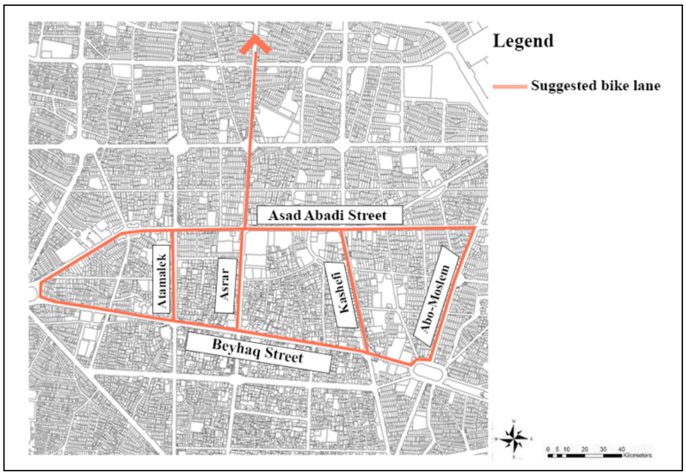


Figure 7. Provision of cycling loop system (The authors)

4.2.1 Alternative 1: Focusing on the Signs and Traffic Standards of Beyhaq Street

This solution is concerned with achieving a complete street structure with the possibility of least intervention in its current situation and strengthening the elements necessary for achieving a complete street, i.e., a subject that has drawn negligible attention over the years. Furthermore, instead of using parking lanes, the cycle path is added to the margin and the physical barriers separating it; at the intersections, cycling lanes are drawn on the surface for bikes only, adjacent to the pedestrian path. In doing so, mobility safety and equal presence of all users in public areas can be ensured. It needs to be emphasized that there will be no changes to the current physical status/situation of this street in this type of intervention. This solution significantly focuses on traffic signs and road equipment. Pedestrian and bicycle lanes need to be repainted at Amir Massoud, Asrar, and Ghaem intersections. Also, repairing traffic lights and installing traffic lights for pedestrians in all directions are considered in this type of intervention. It should be noted that on any pedestrian crossing line, the stop line should be drawn right before t he white crossing with a width of 0.6-0.3 meters. This stop line is drawn at least 1.2 meters before the start of the crossing. It is assumed that applying this solution would not take long and is not costly in practice (Tables 4 & 5).

Segments Indicators	Segment1	Segment2	Segment3	Segment4	Segment5	Segment6
Type of traffic	Mixing ride and public transports. Separating bike path and sidewalk	Mixing ride and public transports. Separating bike path and sidewalk	Mixing ride and public transports. Separating bike path and sidewalk	Mixing routes by vehicle and bus. Separating bike, taxi and sidewalk route	Mixing routes by vehicle and bus. Separating bike, taxi and sidewalk route	Mixing ride and public transport. Separating bike path and sidewalk
Permitted vehicle speed (km/h)	30	30	30	30	30	30
Sidewalk width (m)	3.6	3.5-3.8	3.5-3.4	3	3	3.4
Bike lane (m)	1.5	1.5	1.5	1.5	1.5	1.5
Width of carriageways in each direction(m)	3	3.5	3.5	3.5	3.5	3.5
On-street parking status	Preserving on-street parking on both sides	Removing on-street parking on one side	Removing on-street parking on one side	Preserving the existing on-street parking	Preserving the existing on-street parking	Removing on-street parking on one side

Table 4. Proposed Changes to Alternative 1 at Beyhaq Street Segments (The authors)

Signalized Intersection Indicators	Signalized Intersection1	Signalized Intersection2	Signalize Intersection3
Traffic signal	Installing pedestrian traffic lights	Installing pedestrian traffic lights	Installing pedestrian traffic lights
Bicycle lane status	Defining the cycle path adjacent to the pedestrian lane	Defining the cycle path adjacent to the pedestrian lane	Defining the cycle path adjacent to the pedestrian lane
Turning radius	Preserving existing profile 3-7m	Preserving existing profile 3-7m	Preserving existing profile 3-7m
Quality of guidance signs	Standard transverse signs, Colored flooring, Line drawing and sharpening	Standard transverse signs, Colored flooring, Line drawing and sharpening	Standard transverse signs, Colored flooring, Line drawing and sharpening
Shelter and Refuge	-	-	-
On-street parking	Up to 15 meters before entering the intersection	Up to 15 meters before entering the intersection	Up to 15 meters before entering the intersection

Table 5. Proposed changes to alternative 1 at Beyhaq Street Signalized Intersection (The authors)

4.2.2 Alternative 2: Making Changes to the Share of Each User on Beyhaq Street Space

This approach is aimed at making possible changes to the street with the highest probability (%) of implementation due to (a) sufficient funding and municipal budget and (b) equal servicing for pedestrians, cyclists, and transit. Moreover, the roadway will not be terminated, but it is of lower priority and subject to design limitations due to the strategic location of Beyhaq Street and its commercial role. Of note, this is a medium-term plan that devotes greater emphasis to spatial organization and arrangement of redesigned elements and it aims to resolve the existing problems while relocating and widening the sidewalk and creating speed humps. To design a speed hump, one should consider the necessity of replacing the pavement and increasing the width of speed humps so that it can be greater than the height of the bumping area. Optimal design of speed bumps is essential to reducing driving speed and ensuring pedestrian safety. Bump sides should be attached to the pavement with respect to the surface slope and a distance of 1.8 meters. In this design, in addition to preserving the existing trees, it is necessary to change the separation and buffer boundaries according to the new path (Tables 6 & 7).

4.2.3 Alternative 3: Making Changes to the Space Allocated to Users of Beyhaq Street

This approach is aimed at applying maximum intervention to the current situation and attempts to organize the corresponding environment. In this regard, riding/driving movement is reduced to a minimum and the available space is allocated to public transport and bicycle lanes.

The main focus of this solution is on Segments 3, 4, and 5, attempting to turn every direction into a one-way pathway and removing a crossing line for parking restriction (Segments 4 and 5 from west to east and Segment 3 from east to the west). This measure reduces traffic volume that usually jams the main core of Sabzevar city. Such a heavy traffic volume does not simply vanish, but is distributed mildly to the adjacent streets with a possibility of moderate blockade. In this design model, inter-city movement restrictions facilitate the safety of pedestrians and public transport users; however, the difference between this model and the previous one lies in disrupting the car service level compared to the other three users. The three mentioned segments that constitute the core of Beyhaq Street and Sabzevar city are headed towards human-oriented design with high user safety (Tables 8 & 9).

Segments Indicators	Segment1	Segment2	Segment3	Segment4	Segment5	Segment6
Type of traffic	Mixing ride and public transport. Separating bike path and sidewalk	Mixing ride and public transport. Separating bike path and sidewalk	Mixing ride and public transport. Separating bike path and sidewalk	Mixing route by vehicle and bus Separating bike, taxi and sidewalk route	Mixing route by vehicle and bus Separating bike, taxi and sidewalk route	Mixing ride and public transport. Separating bike path and sidewalk
Permitted vehicle speed (km/h)	30	30	20-30	20-30	20-30	30
Sidewalk width (m)	3.6	4.75-5	5	4	4	4.4
Bike lane width (m)	1.5	1.5	1.5	1.5	1.5	1.5
Transit lane width (m)	-	-	-	3	3	-
Width of carriageways in each direction(m)	3	3	3	3	3	3
Middle Island (m)	-	-	0.5	0.5	0.5	-
On-street parking status	Preserving on-street parking on both sides	Removing on-street parking on one side	Removing on-street parking on one side	Preserving the existing on-street parking	Preserving the existing on-street parking	Removing on-street parking on one side

Table 6. Proposed Changes to Alternative 2 at Beyhaq Street Segments (The authors)

Signalized Intersection Indicators	Signalized Intersection1	Signalized Intersection2	Signalized Intersection3
Traffic signal	Installing pedestrian traffic lights	Installing pedestrian traffic lights	Installing pedestrian traffic lights
Situation of cycling route	Defining the cycling path adjacent to the pedestrian lane	Defining the cycling path adjacent to the pedestrian lane	Defining the cycling path adjacent to the pedestrian lane
Turning radius	Preserving existing profile 3-7m	Preserving existing profile 3-7m	Preserving existing profile 3-7m
Quality of road signs	Standard transverse signs, Colored flooring, Line drawing and sharpening	Standard transverse signs, Colored flooring, Line drawing and sharpening	Standard transverse signs, Colored flooring, Line drawing and sharpening
Shelter and Refuge	-	-	-
On-street parking	Up to 15 meters before entering the intersection	Up to 15 meters before entering the intersection	Up to 15 meters before entering the intersection

Table 7. Proposed changes to alternative 2 at Beyhaq Street Signalized Intersection (The authors)

Segments Indicators	Segment1	Segment2	Segment3	Segment4	Segment5	Segment6
Type of traffic	Mixing ride and public transport. Separating bike path and sidewalk	Mixing ride and public transport. Separating bike path and sidewalk	Completely separate routes	Completely separate routes	Completely separate routes	Mixing ride and public transport. Separating bike path and sidewalk
Permitted vehicle speed (km/h)	30	30	20-30	20-30	20-30	30
Width of sidewalk (m)	3.7	4.5	4.1	3	3	4.5
Width of bike route (m)	1.5	1.5	1.5	1.5	1.5	1.5
Width of public transportation route (m)	-	-	3	6	6	-
Width of carriageways in each direction (m)	2.75	3	3	3	3	2.75
Middle Island (m)	0.5	1	1	1	1	0.5
Pavement friction	low	low	low	low	low	Low
Situation of the on-street parking	Preserving on-street parking on both sides, 2.5 m	Removing the on-street parking on one side, 2.5m	Removing the on-street parking on one side, 2.5m	Preserving the existing on-street parking 2.5m	Preserving the existing on-street parking 2.5m	Preserving on-street parking on one side 2.5m

Table 8. Proposed Changes to Alternative 3 at Beyhaq Street Segments (The authors)

Signalized Intersection Indicators	Signalized Intersection1	Signalized Intersection2	Signalized Intersection3
Traffic signal	Installing pedestrian traffic lights	Installing pedestrian traffic lights	Installing pedestrian traffic lights
Situation of cycling route	Defining the path of the bicycle adjacent to the pedestrian lane	Defining the path of the bicycle adjacent to the pedestrian lane	Defining the path of the bicycle adjacent to the pedestrian lane
Turning radius	Modifying existing profile to 5m	Modifying existing profile to 5m	Modifying existing profile to 5m
Quality of guidance signs	Standard transverse signs, Colored flooring, Line drawing and sharpening	Standard transverse signs, Colored flooring, Line drawing and sharpening	Standard transverse signs, Colored flooring, Line drawing and sharpening
Shelter and refuge	-	-	-
On-street parking	Up to 15 meters before entering the intersection	Up to 15 meters before entering the intersection	Up to 15 meters before entering the intersection

Table 9. Proposed Changes to Alternative 3 at Beyhaq Street Signalized Intersection (The authors)

4.3 Analysis of Alternatives

Extracted criteria as components of alternatives evaluation are listed in 16 rows (Table 10). After determining the weight of each component and their importance in comparison with each other by the AHP technique, the proposed options are ranked by using the TOPSIS technique (Calculations present in the appendix).

Row	criteria	Row	criteria
1	Sidewalk width	9	On-street parking width
2	Ride width	10	Delay of pedestrians crossing the street
3	Island width	11	Barrier width
4	Average turning radius	12	The ratio of operating speed to speed limit
5	The width of the bicycle route	13	Traffic sign
6	Width of the public transport route	14	Bump on the sides of pedestrian crossing lines
7	Public transport delay time at intersections	15	Standard street markings and physical separators on the floor
8	Operating speed	16	Driving control and movement restrictions

Table 10. Extracted Criteria as Components of Alternatives Evaluation (The authors)

According to the similarity index based on Topsis technique, Alternative 3 with similarity index 0.09 was selected as the most desirable and optimal designing and planning option. This alternative is more similar to a complete street pattern in planning principles and it relies on the MMLOS indicators.

Similarity index: Alternative 1 (1)

$$Cl_1 = \frac{0.01}{0.09 + 0.01} = 0.10$$

Similarity index: Alternative 2 (2)

$$Cl_2 = \frac{0.07}{0.05 + 0.07} = 0.58$$

Similarity index: Alternative 3 (3)

$$Cl_3 = \frac{0.1}{0.1 + 0.01} = 0.90$$

4.4 Design Pattern of the Optimal Alternative for Beyhaq Street in Terms of Different Segments and Signalized Intersections

According to the maximum responsiveness to the multi-modal level-of-service indicators, the third alternative with the approach of minimal interventions in the spaces allocated to various users was selected as the best alternative. Various cross-sections of this final solution from the six specified segments of Beyhaq Street and different plans of the three main intersections of Beyhaq Street have been presented to propose a visual demonstration of the third alternative and provide clarity in the expression of the spatial changes. As mentioned earlier, the sidewalk width in Beyhaq Street is currently too small and inefficient compared to the population using it in addition personal vehicles, taxis, buses, and bicycles share the same route which intensifies confusion and chaos in the central core of the city. As observed, changes have been made to facilitate the traffic of all street users: in the first segment by widening the crosswalks, creating a cycle track, and minimizing parking spots and vehicle lanes (Figure 8). The second and sixth segments from Beyhaq Street indicate that in addition to widening the sidewalk and creating a special cycle track, the reversible lane has been separated into one-way lanes by an island to facilitate the pedestrian traffic across the street and parking spots have removed from one side of the streets (Figures 9 & 12). In the third segment of Beyhaq Street, in addition to changes in the width of the sidewalk and the creation of a bicycle path, one of the vehicle's lanes is dedicated to bus traffic, and practically the street is possible for vehicles traffic from east to west (Figure 10). Segments 4 and 5 of Beyhaq Street also have a sensitive traffic position due to their proximity to the main intersection in the city, which is why parking spots have been removed from both sides of the street and have been replaced with taxi lanes, bus lanes, and cycle tracks, and widened sidewalks; and finally became a one-way street (west to east) (Figures 8-15); This separation in the direction of traffic (between 3rth segment and 4&5 segments) reduces a large volume of central chaos.

(P= on-street Park; T= Taxis lane; B= Bus lane)

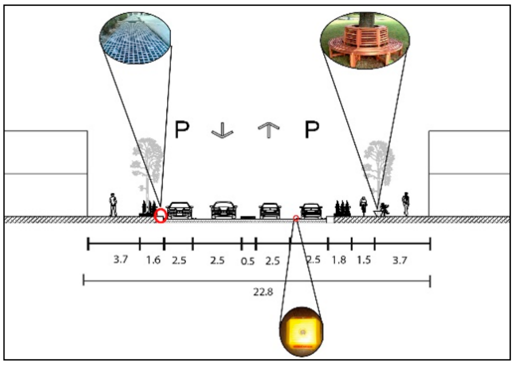


Figure 8. Segment 1: optimal option

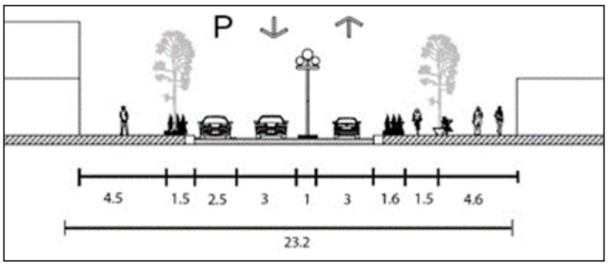


Figure 9. Segmment2: optimal option

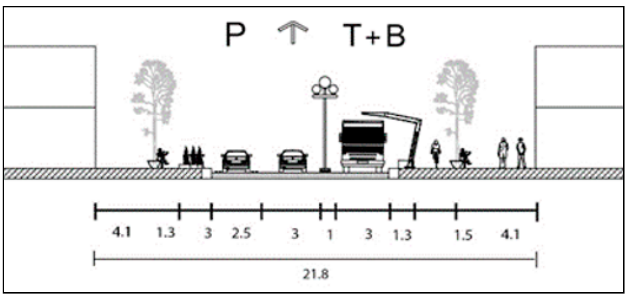


Figure 10. Segment 3: optimal option Figure

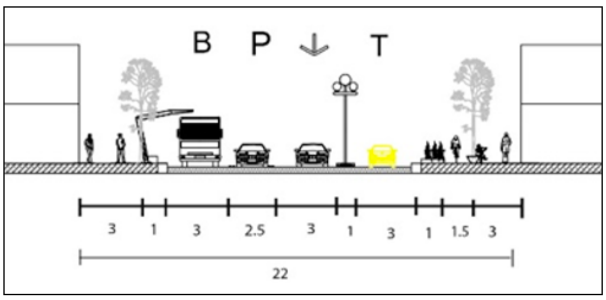


Figure 11. Segments 4 & 5: optimal option

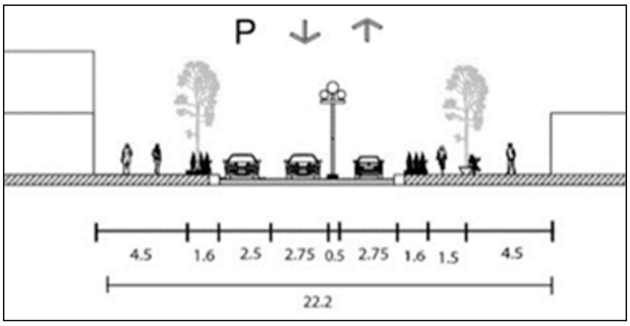


Figure 12. Segment 6: optimal option

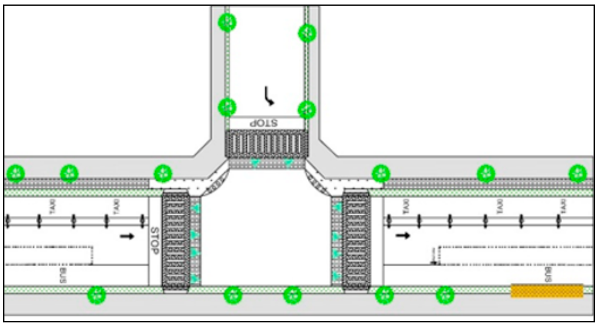


Figure 13 Signalized intersection 3: optimal option

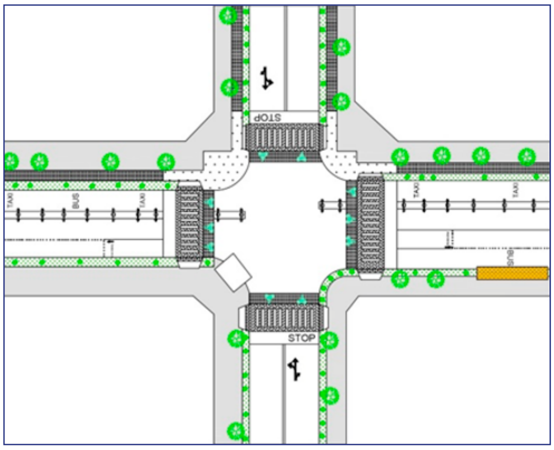


Figure 14 Signalized intersection 2: optimal option

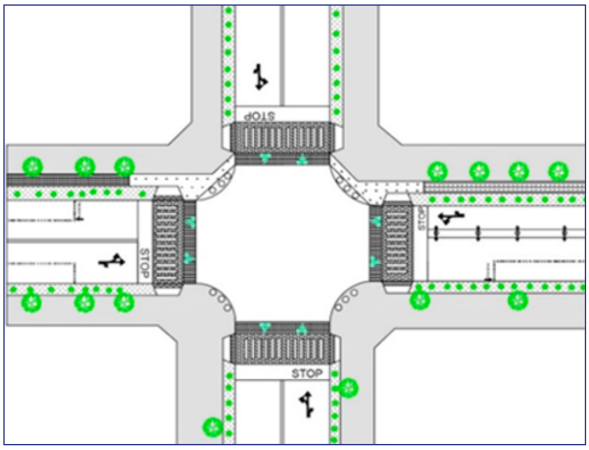


Figure 15. Signalized intersection 1: optimal option

5. CONCLUSION

"[...] How to cut down absolute numbers of surface vehicles and enable those that remain to work harder and more efficiently" (Jacobs, 1961, 349).

As mentioned earlier, the present study mainly seeks to rely on the traffic strategies implemented in Laurier Street as a general planning framework to redesign Beyhaq Street based on an analysis of MMLOS indicators. It must be mentioned that the plans proposed to redesign Beyhaq Street in this regard have been turned into a localized model of the strategies implemented in Laurier Street since an efficient design would not be successful unless it is revised based on the local context, even if inspired by successful practices in high-income countries. We have entered a stage in time when cities choose indigenous trends for design. But how to improve the efficiency and quality of streets and users, especially in cities of middle-income countries, while paying attention to the historical and ancient context of a city, has been an important point to note which this research has adhered to that.

The findings of this study are based on the fact that by adjusting global policies, we can achieve a sustainable model of downtown development in middle-income countries.

Because preserving the historical texture of the city center has high priority, no physical intervention in the adjacent land uses should be suggested, hence there is no need to destroy construction and instead of destruction, must use the existing potentials in combination with the extracted MMLOS indicators. Accordingly, it is possible to re-plan and redesign the existing components of spaces and streets (not historic buildings) to achieve a complete street pattern based on indigenous multi-modal level of services indicators fitting with the best solution.

These effective policies that have been extracted from a case study in high-income countries which can be used to improve the historical context of streets of middle-income countries in effective way are listed below:

- Restricting and controlling vehicles by making the street uni-direction (a contra-flow unidirectional lane in each segment)
- Not allowing buses and truck to enter (bus station located on the main intersections)
- Separation of cycle length at signalized intersections (left turn, right turn, and direct movement) with different traffic signs and lights
- Allocating a special bike lane
- Eliminating On-Street Parking from one side of the street
- Defining special lines for temporary stops along the street
- Legibility and multiplicity in traffic signs
- Limit minute stops and frictions of vehicles
- Create tree bio-swale rows to make hanging around for the non-motorized users more attractive with efficient infrastructure.
- Using leading pedestrian interval (LPI) sign light.
- Determining Park and Ride zone To prevent vehicles from entering the city center

Taking into account all street users in either new or existing cities, the proposed type of planning can regulate the movement of different modes of transportation. Moreover, planning based on the MMLOS can be generalized to other cities and countries, and the quality of streets can be evaluated based on these indicators.

Such a policy is subject to some limitations during research: (a) the most important limitations in middle-income countries are the lack of systems compliant with sustainable development and database deficiencies. Thus, collecting the data and information required for MMLOS analysis which relies on the understanding and analysis of citizen behavior is extremely time consuming and might expand beyond the scope of traffic studies. (b) Considering that the level of service justifies the quality of the service provided to various users, persistent attention to the demands of citizens requires coordinating organizations, public institutions, and teamwork, in which the planner must keep in contact with the people and the context as a mediator rather than an expert, the infrastructure for which has not been formed in many cities of middle-income countries (except their capitals).

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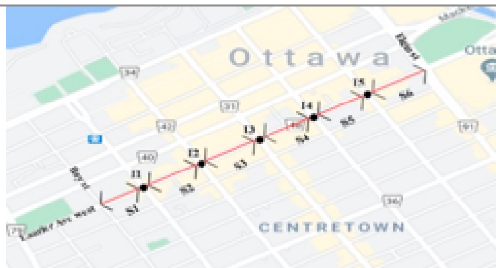
APPENDIX

Laurier Street with a length of about 1076 meters (Bay to Elgin) is an east-west axis and it is home to various uses such as commercial, historical, residential, and office, attracting a large number of people daily. The desired area from this street is the boundary between Bay and Elgin streets, which includes 6 sections and 5 signalized intersections (Open Ottawa, 2019). Table 11 presents the results of the multi-modal level of service analyses on Laurier Street in Ottawa. Of note, the reason for choosing Laurier Street is the similarity of its role, function, street width, and east-west axis to those of Beyhaq Street in Sabzevar.

Table 11. Assessment of Laurier Street current situation, by MMLOS Index (Open Ottawa, 2019 & the authors)

Location			Laurier Street west (in high-income country)					
Functions			Historical and business district					
Sections: East to West (City centre)								
Segments			**S1**	**S2**	**S3**	**S4**	**S5**	**S6**
Street width (m)			20	21	21	20	20	20
segments	PLOS	Sidewalk width (m)	3.5	3.5	3.7	3.7	3.2	2.7
		Boulevard width (m)	0	0	0	0	0	0
		Annual Average Daily Traffic	›3000	›3000	›3000	›3000	›3000	›3000
		On-street Parking	yes	yes	yes	yes	yes	yes
		Operating Speed (km/h)	Average 50 km/h	Average 50 km/h	Average 50 km/h	Averag e 50 km/h	Average 50 km/h	Average 50 km/h
		Final score	B	B	B	B	B	B
	BLOS	Physically Separated Bikeway	×	×	×	×	×	×
		Mixed Traffic						
		Final score	A	A	A	A	A	A
	TLOS	Ratio of average transit travel speed to posted speed limit	-	-	-	-	-	-
		Level/exposure to congestion delay, friction, and incidents	-	-	-	-	-	-
		Final score	-	-	-	-	-	-

Signalized Intersections		**I1**	**I2**	**I3**	**I4**	**I5**
Crossing Distance & Conditions						
Middle island	North	No	No	No	No	No
	South	No	No	No	No	No
	East	No	No	No	No	No
	West	No	No	No	No	No
Total number of crossing lanes	North	2 lanes with no median (120)	3 lanes with no median (105)	3 lanes with no median (105)	2 lanes with no median (120)	2 lanes with no median (120)
	South	2 lanes with no median (120)	3 lanes with no median (105)	3 lanes with no median (105)	2 lanes with no median (120)	3 lanes with no median (105)
	East	2 lanes with no median (120)	2 lanes with no median (120)	2 lanes with no median (120)	2 lanes with no median (120)	2 lanes with no median (120)
	West	2 lanes with no median (120)	2 lanes with no median (120)	2 lanes with no median (120)	2 lanes with no median (120)	2 lanes with no median (120)
Refuge island	North	No (-4)	No (-4)	No (-4)	No (-4)	No (-4)
	South	No (-4)	No (-4)	No (-4)	No (-4)	No (-4)
	East	No (-4)	No (-4)	No (-4)	No (-4)	No (-4)
	West	No (-4)	No (-4)	No (-4)	No (-4)	No (-4)

Signalized Intersections / PLOS	Timing and staging of signs and traffic lights						
	Turning left	North	Protected=0	Protected=0	Protected=0	Protected=0	Protected=0
		South	Protected=0	Protected=0	Protected=0	Protected=0	Protected=0
		East	Protected=0	Protected=0	Protected=0	Protected=0	Protected=0
		West	Protected=0	Protected=0	Protected=0	Protected=0	Protected=0
	Turning right	North	Protected/permissive = -5	No right turn = 0	Protected/permissive = -5	Protected/permissive = -5	No right turn = 0
		South	No right turn = 0	Protected/permissive = -5	Protected/permissive = -5	No right turn = 0	Protected/permissive = -5
		East	No right turn = 0	Protected/permissive = -5	Protected/permissive = -5	No right turn = 0	Protected/permissive = -5
		West	Protected/permissive = -5	No right turn = 0	Protected/permissive = -5	Protected/permissive = -5	No right turn = 0
	Right turns on red	North	Prohibited = 0	Prohibited = 0	Prohibited = 0	Prohibited = 0	Prohibited = 0
		South	Prohibited = 0	Prohibited = 0	Prohibited = 0	Prohibited = 0	Prohibited = 0
		East	Prohibited = 0	Prohibited = 0	Prohibited = 0	Prohibited = 0	Prohibited = 0
		West	Prohibited = 0	Prohibited = 0	Prohibited = 0	Prohibited = 0	Prohibited = 0
	Pedestrian traffic signals	North	Yes = 0	Yes = 0	Yes = 0	Yes = 0	Yes = 0
		South	Yes = 0	Yes = 0	Yes = 0	Yes = 0	Yes = 0
		East	Yes = 0	Yes = 0	Yes = 0	Yes = 0	Yes = 0
		West	Yes = 0	Yes = 0	Yes = 0	Yes = 0	Yes = 0
	Corner Radius						
	Corner Radius (> 5m to 10m = -5) (> 3m to 5m = -4) (Less than/equal to 3m = -3) (No right turn = 0)	North	-4	0	-4	-4	0
		South	0	-4	-4	0	-4
		East	0	-4	-4	0	-4
		West	-4	0	-4	-4	0
	Crosswalk Treatment						
	(Textured/colored pavement = -4)	North	-4	-4	-4	-4	-4
		South	-4	-4	-4	-4	-4
		East	-4	-4	-4	-4	-4
		West	-4	-4	-4	-4	-4
	Score sum	North	100	97	88	103	112
		South	109	88	88	112	88
		East	109	103	103	112	103
		West	100	112	103	103	112
	Final score	North	A	A	B	A	A
		South	A	B	B	A	B
		East	A	A	A	A	A
		West	A	A	A	A	A
	Time taken for pedestrians to cross the street						
	Average pedestrian Delay		>20 to 30 sec	>20 to 30 sec	>20 to 30 sec	>20 to 30 sec	>20 to 30 sec
	Final score		c	c	c	c	c
BLOS	Physically Separated Bikeway		Two-stage, left-turn bike box; ≤ 50 km/h	Two-stage, left-turn bike box; ≤ 50 km/h	Two-stage, left-turn bike box; ≤ 50 km/h	Two-stage, left-turn bike box; ≤ 50 km/h	Two-stage, left-turn bike box; ≤ 50 km/h
	Mixed Traffic	Right-turn Lane and Turning Speed of Motorists	-	-	-	-	-
		Cyclist Making a Left-turn and Operating Speed of Motorists	-	-	-	-	-
	Final score		A	A	A	A	A
TLOS	Delay		-	-	-	-	-
	Final score		-	-	-	-	-

AHP TECHNIQUE CALCULATIONS

The Analytic Hierarchy Process (AHP) is known as Multi-criteria Decision-Making, which developed by Thomas L. Saaty in the 1970s and has been refined since then. It is a comprehensive and flexible approach to solving complex problems at different levels using multi-criteria methods. A theory based on „Relative Measurement“. In relative measurement, the focus is not on accurately measuring the values but on the ratios between them. In relative measurement, attention is paid to knowing the importance and value of each criterion in comparison with the other criterion. The importance of each of the criteria is thus measured by forming the Pairwise Comparison Matrix, which applies the SAATY scale comparison scale (Table 12). In line with this research, the components are placed in relation to each other according to Table 13.

Scale	Numerical Rating	Reciprocal
Extremely Preferred	9	1/9
Very strong to etremely	8	1/8
Very strong preferred	7	1/7
Strongly to very strongly	6	1/6
Strongly preferred	5	1/5
Moderately to strongly	4	1/4
Moderately preferred	3	1/3
Equally to moderately	2	1/2
Equally preferred	1	1

Table 12. Saaty's Scale of Relative Importance (Saaty,2005)

Then the matrix must be normalized. To normalize the matrix, each matrix entry needs to be divided by the sum of its columns. The contribution of each criterion to the organizational goal is determined by calculations made using the Eigenvector. The Eigenvector shows the relative weights between each criterion; it is obtained in an approximate manner by calculating the mathematical average of all criteria(Vargas, 2010). In the other hand, the weight of each criterion is calculated from the row average of the entries in the normalized matrix. The weights for the criterias related to this research, those are shown in Table 10, was calculated as below (Table 14).

In order to measure the validity and accuracy of the weighting, the compatibility rate must be calculated. It is essential to know that, the weighting will be valid if the calculated compatibility rate (CR) becomes less than 0.1.

$$CR = \frac{CI \quad (1)}{RI \quad (2)} < 0.1$$

1) $CI = \frac{\lambda_{max} - n}{n-1}$

- To find λ_{max}, in the first step, the pairwise comparisons matrix (which isn't normalize) multiply by the relative weights obtained. Then divide the result by the vector relative weights of the indices to obtain the compatibility vector. Finally, the calculated arithmetic mean of the elements of this vector is called λ_{max}.
- n = Number of components

2) RI = The random consistency index (according to Table 15)

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 15. The random consistency index (Saaty, 2005)

Based on this study, the compatibility index (CI) of the criteria was calculated, which was equal to 0.12. The CR was measured at 0.07; therefore, the weights of the indexes were quite accurate and valid.

index	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.00	3.00	3.00	7.00	1.00	1.00	2.00	1.00	5.00	2.00	3.00	1.00	2.00	2.00	3.00	0.50
2	0.33	1.00	0.33	2.00	0.33	0.33	0.20	2.00	1.00	0.33	0.50	0.50	0.33	0.33	0.33	0.20
3	0.33	3.00	1.00	2.00	0.50	0.50	0.50	4.00	2.00	1.00	2.00	1.00	0.50	1.00	0.50	0.33
4	0.14	0.50	0.50	1.00	0.14	0.14	0.33	0.50	0.50	0.50	0.33	1.00	0.50	0.33	0.50	0.33
5	1.00	3.00	2.00	7.00	1.00	1.00	2.00	2.00	3.00	2.00	2.00	2.00	2.00	2.00	3.00	2.00
6	1.00	3.00	2.00	7.00	1.00	1.00	0.50	1.00	3.00	2.00	2.00	1.00	0.50	0.50	0.50	0.33
7	0.50	5.00	2.00	3.00	0.50	2.00	1.00	2.00	2.00	1.00	2.00	1.00	3.00	2.00	3.00	1.00
8	1.00	0.50	0.25	2.00	0.50	1.00	0.50	1.00	0.50	0.50	0.50	1.00	0.50	0.33	0.50	0.20
9	0.20	1.00	0.50	2.00	0.33	0.33	0.50	2.00	1.00	0.33	0.50	0.25	1.00	0.33	1.00	0.14
10	0.50	3.00	1.00	2.00	0.50	0.50	1.00	2.00	3.00	1.00	2.00	1.00	1.00	1.00	1.00	0.50
11	0.33	2.00	0.50	3.00	0.50	0.50	0.50	2.00	2.00	0.50	1.00	0.50	0.33	0.50	0.50	0.14
12	1.00	2.00	1.00	1.00	0.50	1.00	1.00	1.00	4.00	1.00	2.00	1.00	0.50	0.33	0.50	0.25
13	0.50	3.00	2.00	2.00	0.50	2.00	3.00	2.00	1.00	1.00	3.00	2.00	1.00	1.00	2.00	2.00
14	0.50	3.00	1.00	3.00	0.50	2.00	0.50	3.00	3.00	1.00	2.00	3.00	1.00	1.00	2.00	1.00
15	0.33	3.00	2.00	2.00	0.33	2.00	0.33	2.00	1.00	1.00	2.00	2.00	0.50	0.50	1.00	2.00
16	2.00	5.00	3.00	3.00	0.50	3.00	1.00	5.00	7.00	2.00	7.00	4.00	0.50	1.00	0.50	1.00

Table 13. Pairwise Comparison Matrix based on reaserch goal

Criterias	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Weights of Criterias	0.1	0.03	0.05	0.03	0.11	0.07	0.09	0.02	0.03	0.06	0.04	0.0.5	0.07	0.07	0.06	0.12

Table 14. The weights of Multi-Modal Level of Service indicators by AHP method

TOPSIS TECHNIQUE CALCULATIONS

The TOPSIS is a multiple-attribute decision-making (MADM) method that ranks options. In this method, the two concepts of „ideal solution" and „similarity to the ideal solution" are used. The ideal solution, as its name implies, is the solution that is the best in every way, which generally does not exist in practice, and the options try to get closer to it. In order to measure the similarity of an option to an ideal and counter-ideal solution, the distance of that option from the ideal and non-ideal solution is measured. The options are then evaluated and ranked based on the ratio of the distance from the ideal solution to the total distance from the ideal and non-ideal conditions. The word TOPSIS is derived from the initials of the Technique for Order of Preference by Similarity to Ideal Solution.

The steps of the TOPSIS method are as follows:

1. After making the decision matrix, the options are placed in the rows and the components in the columns.

2. The decision matrix is normalized by the following formula:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}$$

3. In the weighted normalized decision matrix as the third step, the weight of the criteria obtained from other techniques (AHP Technique) is multiplied by the normalized matrix. The weighted matrix based on the options proposed in this research is shown below (Table 16).

4. Then the ideal and non-ideal solutions are determined. It should be noted that the criteria are either positive or negative. For positive criteria, the criteria that improve the system, the ideal solution is equal to the largest element of the column cell and the counter-ideal is equal to the smallest element; for negative criteria it's vice versa.

   - For criteria that have a positive burden, the positive ideal is the highest value of that criterion.
   - For criteria that have a positive burden, the negative ideal is the lowest value of that criterion.
   - For criteria that have a negative burden, the positive ideal is the lowest value of that criterion.
   - For criteria that have a negative burden, the negative ideal is the highest value of that criterion.

   Determining the ideal and non-ideal options based on the components of this research is as follows (Table 17).

5. To calculate the distance between the options and the ideal and counter-ideal solutions, the following equations are used; and table 18 shows the distances between 3 alternatives and ideal and non-ideals conditions for this study :

$$d_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2}$$

$$d_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}$$

d_i^+	d_i^-
$d_1^+ = 0.09$	$d_1^- = 0.01$
$d_2^+ = 0.05$	$d_2^- = 0.07$
$d_3^+ = 0.01$	$d_3^- = 0.1$

Table 18. The distance between the research alternatives and the Ideal and non-ideal conditions

6. Finally, by calculating the similarity index with the following equation, the final rank of the options is obtained (The calculations related to this research are presented in the main text of the research).

$$cl_i^* = \frac{d_i^-}{d_i^- + d_i^+}$$

* As much as this number gets closer to 1, it shows the superiority of the option.

Criteria type	+	-	+	-	+	+	-	-	-	-	+	+	+	+	+	+
criteria	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Alternative 1	0.05	0.01	0	0.01	0.06	0.02	0.05	0.02	0.01	0.03	0.02	0.02	0.04	0	0.03	0.03
Alternative 2	0.06	0.01	0.02	0.01	0.06	0.02	0.05	0.01	0.01	0.03	0.02	0.03	0.04	0.05	0.03	0.06
Alternative 3	0.05	0.01	0.04	0.01	0.06	0.05	0.02	0.01	0.01	0.03	0.02	0.03	0.04	0.05	0.03	0.08

Table 16. Weighted normalized decision matrix

Criteria type	+	-	+	-	+	+	-	-	-	-	+	+	+	+	+	+
criteria	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
ideal	0.06	0.01	0.04	0.01	0.06	0.05	0.02	0.01	0.01	0.03	0.02	0.03	0.04	0.05	0.03	0.08
Non- ideal	0.05	0.01	0	0.01	0.06	0.02	0.05	0.02	0.01	0.03	0.02	0.02	0.04	0	0.03	0.03

Table 17.Determining the ideal and non-ideal conditions