

Exploring the Quality-of-life Satisfaction in the Historical Fabrics of Iran Through Machine Learning Models

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Abstract

Historical city centres are quite often left out of the urban development process, especially when population growth is very rapid. Therefore, they are confronted with severe difficulties affecting the quality of life (QOL) of their residents. An adequate QOL is essential to anchor the local population in these valuable historical areas. Keeping their traditional ways of life is critical to preserve their heritage, but almost no comprehensive study has been done on the subject in Iran. To address this deficiency, a multivariable analysis was carried out based on an extensive survey that counted with the participation of more than 1800 inhabitants of the old city centres of Yazd, Ardakan, Naeen and Kashan. The QOL (dependent variable) was related to 21 independent variables, covering a wide range of physical, social, economic, environmental, and institutional aspects, selected from a thorough review of the theoretical literature. To discover the patterns underlying the collected data, several different parametric and non-parametric algorithms such as CHAID, Logistic Regression, NEURAL NET, C5.0 and C&R Tree have been examined. The C5.0 model showed the highest overall accuracy and was used to select the best predictors of QOL satisfaction for the residents of these city areas: 1) quality of buildings and streets, 2) safety and security, 3) administrative services and 4) vehicle accessibility. The knowledge gathered should assist Iranian decision-makers and planners develop comprehensive regeneration plans for historical city areas and better incorporate social sustainability aspects.

Keywords: Quality of life (QOL); historical urban fabrics; urban regeneration; data mining

Citation

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Explorando la satisfacción de la calidad de vida en los tejidos históricos de Irán a través de modelos de aprendizaje automático

Resumen

Los centros históricos de las ciudades a menudo quedan fuera del proceso de desarrollo urbano, especialmente cuando el crecimiento de la población es muy rápido. Por lo tanto, se enfrentan a graves dificultades que afectan la calidad de vida (CV) de sus residentes. Una CV adecuada es esencial para anclar a la población local en estas valiosas áreas históricas. Mantener sus formas de vida tradicionales es fundamental para preservar su herencia, pero casi no se ha realizado un estudio exhaustivo sobre el tema en Irán. Para abordar esta deficiencia, se llevó a cabo un análisis multivariable basado en una encuesta que contó con la participación de más de 1.800 habitantes de los centros de las ciudades antiguas de Yazd, Ardakan, Naeen y Kashan. La CV (variable dependiente) se relacionó con 21 variables independientes, que abarcan una amplia gama de aspectos físicos, sociales, económicos, ambientales e institucionales, seleccionadas a partir de una revisión exhaustiva de la literatura teórica. Para descubrir los patrones subyacentes a los datos recopilados, se examinaron varios algoritmos paramétricos y no paramétricos como CHAID, regresión logística, NEURAL NET, C5.0 y C&R Tree. El modelo C5.0 mostró la precisión general más alta y se utilizó para seleccionar los mejores predictores de la satisfacción de CV para los residentes de estas áreas de la ciudad: 1) calidad de edificios y calles, 2) seguridad y protección, 3) servicios administrativos y 4) accesibilidad vehicular. El conocimiento recopilado debería ayudar a los responsables de la toma de decisiones y los planificadores iraníes a desarrollar planes integrales de regeneración para las áreas históricas de las ciudades e incorporar mejor los aspectos de sostenibilidad social.

Palabras clave: Calidad de vida (CV); tejidos urbanos históricos; regeneración urbana; procesamiento de datos

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1. Introduction

The rapid growth of urbanisation in recent decades, despite its merits, like labour specialisation, economies of scale and creativity (Glaeser, 2011), has had unpleasant consequences on the quality of life (QOL) of residents at various urban scales (Berry & Okulicz-Kozaryn, 2011). QOL is a concept that has been often discussed about the problems cities are confronted with, some of them clearly exposed by the Covid crisis. However, QOL is a broad and multi-dimensional concept that, in addition to economic concerns, incorporates social and ecological aspects (Berger-Schmitt, 2002), and thus it must be addressed from a wide variety of disciplines (El Din *et al.*, 2013). Indeed, problems such as poverty, unemployment, environmental pollution, insecurity, social crime, congestion, lack of services, lack of sense of place, lack of accessibility, etc., should not be approached from a single perspective.

Historical fabrics within cities have been particularly affected by rapid urban changes, as most governments tend to favour growth and modernisation, especially in developing countries. The attention of most decision-makers and policymakers has focused on new settlements, and anything old or in a traditional style was considered of little value and was torn down or, at best, ignored (Steinberg, 1996). This has led to an acute decline in QOL in these urban areas and caused local residents to leave them, intensifying the process of degeneration. This decay persists despite the fact that historical urban areas represent a unique link with the past: a physical manifestation of the social and cultural traditions that have been instrumental in giving the modern city and society its meaning and character (Steinberg, 1996). Besides being a major cultural and social asset of many countries, historical city centres offer considerable potential as an attraction both for locals and visitors (Balbo, 2012). Preserving this valuable heritage should thus be a priority for any good society. The revitalisation and prosperity of old urban tissues can only be ensured if the inhabitants' QOL is good enough to prevent their abandonment.

To improve the QOL in decaying urban areas, urban regeneration is considered the most effective procedure through its effects on physical, economic, social and environmental aspects (Urbact.eu, 2016). The urban regeneration term encompasses actions such as urban rehabilitation or urban renovation that have a narrower focus. It aims at the sustainable development of city areas with severe problems (Alpopi & Manole, 2013) and includes new infrastructure, infill housing, the transformation of historic buildings for workplaces, education and tourism, culture-led revitalisation and place-making (Lehmann, 2019).

Despite the critical importance of QOL to revitalise historical city centres, very few studies have been conducted on this subject in Iran. Even those lack empirical evidence and are mainly theoretical. The lack of practical and reliable data on historical fabrics and, specifically on QOL satisfaction, has made it impossible to design appropriate solutions to properly preserve these fabrics and ensure their traditional role in the heart of the cities. Most of the existing studies have a very limited scope, do not abide by a comprehensive framework and are supported by a small number of participants, mostly at the neighbourhood level. They are not, therefore, adequate to reflect the complex situation of historical areas and to propose the necessary comprehensive solutions for their regeneration. Hence, it was considered essential, within our research on the regeneration of historical urban fabrics in Iran, to undertake a holistic study, with high participation of residents, to gain a deeper understanding of the main predictors of QOL satisfaction in these areas, as a basis to define appropriate intervention strategies.

The first step of the study was to create a list of the most prominent variables affecting QOL satisfaction. A thorough review of the literature allowed identifying the indicators commonly used in regeneration plans and selecting those that are more pertinent for the Iranian case.

They were then used in the preparation of a questionnaire to carry out an ad-hoc survey in several Iranian historical city centres. The survey counted with high participation of residents and, according

to reliability indicators, the information obtained is consistent and trustworthy. The collected data made it possible to discover behavioural patterns or, in other words, the most important predictors of QOL satisfaction from residents' perspectives through data mining using Machine Learning (ML) models for the first time in Iran. This study provides, thus, through realistic data and research-supported results, an empirical basis to assess QOL. This should contribute to future guidelines and action plans for regenerating historical centres in Iran at different scopes and scales.

2. Literature Review

QOL is a multi-dimensional and broad concept which, due to its importance for society, has been explored and studied in many different disciplines, including psychology, economics, environmental sciences and, mainly, in urban planning (Grayson & Young, 1994; McMahon, 2002; Savageau, 2007; Ali et al., 2009; Li et al., 2009; European Union, 2013; Węziak-Białowolska, 2016; Macke et al., 2018; Kaklauskas et al., 2018; Moeinaddini et al., 2020). QOL encompasses a wide range of variables covering psychological, social, economic, and environmental aspects. Due to the multifaceted nature of this concept, scholars, and academic institutions, according to their goals and approaches, have produced specific indicators for these variables.

However, a revision of the theoretical literature shows that most authors agree that QOL is linked to two main dimensions: psychological and environmental (Massam, 2002). What is clear is that QOL satisfaction is a condition that results from comparing the expectations of individuals in society with their current situation (Insch & Florek, 2008). As Wish (1986) indicates, QOL in cities can be defined generally as "the relation between the individual perceptions and the feelings of people, and their experiences within the space they live in". Regardless of age, gender, and beliefs, people are inherently inclined to live in better and higher quality conditions. As Faggian & Royuela (2010) state, "people decide where to live based on their evaluation of the overall QOL offered by different locations". Indeed, as Tiebout (1956) already pointed out, people are moving to places that better meet their priorities. Therefore, QOL satisfaction is recognised as one of the main reasons for intra-city and intra-neighbourhood movements (Frijters et al., 2011; Nowok et al., 2018).

Many planners, politicians, governmental and non-governmental organisations have tried to change the situation of derelict areas by improving QOL (Massam, 2002). This requires quantification, so QOL assessment has been attempted in many countries by different academic studies (Lane, 1989; Risser et al., 2006; Trip, 2007; Williams et al., 2008; Shu & Zhu, 2009; European Union, 2013; Węziak-Białowolska, 2016). Despite these studies, it is not very clear what are the key determinants of QOL in decaying urban areas and in those keeping valuable traditional tissues.

In general, this lack of consensus has not prevented most studies and projects from using a set of ad-hoc economic, social, political and environmental approaches and specific indicators to determine and assess the QOL in their specific areas (Massam, 2002). Some researchers stressed physical indicators like quality of streets and buildings, housing, land use, pedestrian and vehicle accessibility, public transport and public spaces as measures of QOL (Lynch & Rodwin, 1958; Lynch, 1984; Jacobs & Appleyard, 1987; Murdie et al., 1992; Smith et al., 1997; Türksever & Atalik, 2001; Mccrea et al., 2005; Insch & Florek, 2008; Zenker et al., 2013; Streimikiene, 2015; Kährlik et al., 2016; Lee & Sener, 2016), while others highlighted the social aspects such as safety, happiness and morale, social cohesion, well-being, social interactions and networks (Weidemann et al., 1982; Dahmann, 1983; Parkes et al., 2002; Clifton et al., 2008; Ross, 2011; Helsley & Zenou, 2014; Okulicz-Kozaryn & Mazelis, 2018; Garau & Pavan, 2018).

On the other side, some scholars underlined personal/environmental health and healthcare services as the primary component for QOL (Wheeler, 1991; Marlin, 1992; Smith et al., 1997; Türksever & Atalik,

2001; Baum *et al.*, 2010; Wang *et al.*, 2011; Zenker *et al.*, 2013). There is a consensus among experts on the importance of accessibility to services like education (Ross & Willigen, 1997; Mccrea *et al.*, 2005; Baum *et al.*, 2010; Zenker *et al.*, 2013), cultural services (Ge & Hokao, 2006; Zenker *et al.*, 2013; Steiner *et al.*, 2015), sport and recreational facilities (Driver *et al.*, 1991; Türksever & Atalik, 2001; Lloyd & Auld, 2002; Insch & Florek, 2008) and retail shops and food amenities (Nayga Jr & Weinberg, 1999; Witten *et al.*, 2003; Zenker & Rütter, 2014; Öner, 2017) for residents' QOL. In addition to the aforementioned factors, some studies also highlight economic and social aspects, such as unemployment, poverty, housing prices, job opportunities and life expenses (Warr, 1987; Room, 1995; Berger-Schmitt, 2002; Nelson & Saegert, 2009; McDonald, 2012; Zenker *et al.*, 2013; Streimikiene, 2015; Okulicz-Kozaryn & Mazelis, 2018). Air/noise pollution, cleanness, crowding, and landscape are also among the most relevant environmental factors in many studies (Pacione, 2003; Rehdanz & Maddison, 2008; Baum *et al.*, 2010; Zenker *et al.*, 2013; Węziak-Białowolska, 2016).

The last important aspect of QOL in cities, which is often disregarded, is related to the administrative and institutional services and their legal context. According to Frey & Stutzer (2000), institutional conditions and democracy directly affect happiness and well-being. Some scholars stressed that good governance, the rule of law, corruption control, and fair public services are features that can be influential in the development and growth of a country or a city and eventually in QOL (Rothstein & Teorell, 2008; Holmberg *et al.*, 2009; Charron *et al.*, 2014). Some more concrete effects associated with the institutional and public services, such as building permits or subsidies and tax exemptions in building renovations, directly impact residents' appreciation of their QOL (Turró, 2012).

Given the focus of the current research on historic urban areas in Iran, two additional specific variables, "bazaars" and "mosques", that have a very significant role in these areas, although they may not be so relevant in other parts of the cities, were also considered. According to Soltanzadeh (2013), these two urban facilities have been considered, for a long time, as the main factors of vitality, liveliness and active social interactions in these fabrics. As Mashhadizadeh Dehaghani (1995) states, "bazaars" and "mosques" are two main pillars of historical cities in Iran. Mosques (specifically the Grand Mosque) in the historical cities, in addition to their religious role, have had a very strong political and social function, and many events, including political appointments, public meetings, social discourses, etc., were happening in these places. The bazaar was the backbone of Iranian historical cities (Habibi, 2018) and, besides an economic space, it was a place for many social activities (Daneshpour & Roustaa, 2013). Therefore, having always been associated with the social life of the residents of historical areas in Iran, mosques and bazaars must be included in the QOL assessment. Given the vast array of variables mentioned above, it can be concluded that the QOL concept is not fixed and varies depending on the experts applying it and even on the perceptions of the inhabitants living in a city or a particular neighbourhood. However, this broad literature survey allows conceptualising the QOL concept to integrate the basic dimensions most affecting human life, including physical, social, economic, environmental and institutional aspects. It is not possible, however, at this stage, to define a model from the literature review that would somehow quantify the concept based on a concrete set of variables and even less so if it had to be applied to old city areas of Iran, which have never been analysed through an extensive survey focusing on QOL.

Indeed, none of the studies carried out discussing the QOL issue in some cities of Iran (Habibi, 2014; Poorahmad & Zareei, 2015; Yazdanpanah Shahabadi & Sajadzadeh, 2018; Bastanian Shahgoli *et al.*, 2018; Mehdizadeh Saradj *et al.*, 2018; Moayedfar & Eshaghi, 2019) has involved a sufficiently large number of participants to explore the QOL based on residents' perceptions properly. Lacking a solid background on these perceptions from former works, it was necessary to establish a method to obtain the information required and then to define a model integrating those variables identified as more relevant into a single comprehensive formulation for a single QOL indicator adapted to historical city areas.

Since personal perceptions are critical to identifying the factors affecting QOL satisfaction, an essential part of the method was the execution of a survey to explore the residents' perceptions of these areas regarding social, economic, physical, environmental, and institutional features.

3. Methodology

As already mentioned, there is no accepted definition of QOL or clear identification of the factors determining it. However, what is clear is that QOL depends on the specific locational and social circumstances of the community to be analysed. So, to identify and quantify the most important factors affecting historic urban areas in Iran, we had to collect a significant amount of local information, including from the questionnaires filled by a representative sample of residents. This information is obviously disparate and sometimes redundant or contradictory and requires a type of analysis that has been made available to researchers in the past few years. In our case, we opted for ML models to try and understand the behavioural patterns related to the QOL satisfaction of the residents of Iran's historical fabric. ML is a subset of artificial intelligence that allows systems to learn and progress automatically without explicit programming (Mitchell, 1997). According to Hawkins & Blakeslee (2004), the primary idea behind ML models is to find a way to predict the future. In fact, their main goal is to enable computers/systems to learn based on input data automatically and apply decision patterns to make predictions without human intervention. Based on a representative sample of input data known as "training data", the models are applied to the bulk of the data and adapted to make predictions and check their quality.

In fact, when dealing with a complex task or problem that traditional methods cannot solve, or when there is a massive amount of data and variables that cannot be processed and calculated by humans using traditional methods, ML presently appears as the best option. One of the main reasons to choose ML models in this research is that they use inductive reasoning to conclude, while traditional analytics generally use deductive reasoning. Moreover, traditional analytical methods often require some prior understanding of the issue, while ML models perform differently. These models can quickly adapt themselves to changing conditions. This superiority is of great importance concerning the analysis of cities and their residents, as they are constantly affected by changing circumstances. A significant difference between ML models and traditional statistical methods is in their purpose, as the first method focuses as much as possible on accurate predictions, while the latter focuses on inferring relationships between variables (Azzolina *et al.*, 2019). However, the main difference between ML and traditional statistical methods is that ML makes predictions based on a set of examples with no predefined rules or programs, something that suited perfectly the data collected and the objective of this research. On the other hand, the data mining from the questionnaires and the accuracy comparisons among the different models used are innovative, as ML has seldom been used in social sciences despite the rapid development and expansion of these techniques in other fields.

3.1 Case study and data collection

In the present study, after an extensive analysis of different cities in Iran, with the collaboration of academic professors of Polytechnic University of Catalonia (UPC) and Iran University of Science and Technology (IUST), the four historical city centres of Yazd, Kashan, Ardakan and Naeen have selected as case studies. Their current situation and some recurrent shared features suggest that they could be representative of most historical urban fabrics in Iran. As already mentioned, to obtain the required data, an extensive survey had to be carried out to explore different aspects of urban QOL satisfaction based on the perception of residents about their living environment.

The questionnaire consisted of two parts, one related to the dependent variable and the other to the independent variables. A set of predetermined questions to allow the quantification of these variables

were reviewed by experts in the subject. Before distributing the questionnaire, its reliability was checked using a pilot sample of 50 respondents. The Cronbach's alpha coefficient for this sample was calculated to be 0.86, which is highly acceptable and confirms the reliability of the data set (Cronbach, 1951; Cortina, 1993).

The survey was carried out in two stages in 2019 and 2020 (taking, in total, about five months) with the participation of 1,800 residents, equally distributed and involving different social and demographic groups, using a Stratified Sampling Technique (stratified by neighbourhoods). Table 1 provides some demographic information regarding the participants. The remarkable point was that women were less willing to participate in the research, which can be attributed to some cultural and religious beliefs. However, an attempt was made to make the ratio of men and women in the survey as equal as possible (in total, approximately 59% men and 41% women). To prevent misunderstandings in answering the questions and increase the accuracy, over 90% of all the questionnaires were completed by the main researcher in person. In some cases, telephone interviews with residents have been used to complete the data with the collaboration of municipalities. Small gifts to the respondents have stimulated the answering rate.

Table 1. Basic demographic information of participants in the current survey

Historic city centre		Kashan	Naeen	Ardakan	Yazd
Population (approx.)		8,000	2,000	3,000	7,000
Gender (%)	M	55	63	60	58
	F	45	37	40	42
Age			15-30:	28%	
			31-45:	32%	
			46-65:	19%	
			>65:	21%	
Education			Illiterate:	11%	
			Some elementary:	30%	
			High school:	35%	
			University degree:	24%	
Marital Status			Married:	62%	
			Not currently married:	38%	

Source: Authors.

3.2 Variables

Dependent variable

The dependent variable of our model was QOL satisfaction in the historical city centres of Iran. The residents included in our sample were explicitly asked to answer "if they were satisfied to live in their historical fabric" based on a four-point scale: 1: strongly disagree, 2: somewhat disagree, 3: somewhat agree and, 4: strongly agree.

Independent variables

A complete list of the most important variables determining QOL, derived from the revision of the theoretical literature, was used to select the independent variables, covering a wide range of physical, social, economic, environmental and institutional aspects. The list in its final format consisted of 21 variables (shown in Table 2). A four-point scale ranging from 1: not at all satisfied, 2: rather unsatisfied, 3: rather satisfied and 4: very satisfied was used, and residents were asked to express their satisfaction degree for every single variable.

Table 2. Independent variables used in the research to assess the QOL

Item	Independent Variables	Main Corresponding Sources
1	Access to health care services	(Wheeler, 1991; Marlin, 1992; Smith <i>et al.</i> , 1997; Türksever & Atalik, 2001; Baum <i>et al.</i> , 2010; Wang <i>et al.</i> , 2011; Zenker <i>et al.</i> , 2013)
2	Access to green and public spaces (pedestrian area, playgrounds, etc.)	(Lynch & Rodwin, 1958; Lynch, 1984; Jacobs & Appleyard, 1987; Murdie <i>et al.</i> , 1992; Smith <i>et al.</i> , 1997)
3	Access to educational services	(Ross & Willigen, 1997; Mccrea <i>et al.</i> , 2005; Baum <i>et al.</i> , 2010; Zenker <i>et al.</i> , 2013)
4	Access to sporting and recreational services	(Driver <i>et al.</i> , 1991; Türksever & Atalik, 2001; Lloyd & Auld, 2002; Insch & Florek, 2008)
5	Access to public transport (bus, metro, etc.)	(Türksever & Atalik, 2001; Mccrea <i>et al.</i> , 2005; Insch & Florek, 2008)
6	Access to public utilities	(Dimian & Barbu, 2012; Bridge <i>et al.</i> , 2016; Rao & Pachauri, 2017)
7	Access to retail shops and food services	(Nayga Jr & Weinberg, 1999; Witten <i>et al.</i> , 2003; Öner, 2017; Zenker & Rütter, 2014)
8	Access to cultural facilities	(Ge & Hokao, 2006; Zenker <i>et al.</i> , 2013; Steiner <i>et al.</i> , 2015)
9	Access to mosques and their physical condition	(Abdel-Hady, 2010; Soltanzadeh, 2013; Falamaki, 2015)
10	Safety and security	(Weidemann <i>et al.</i> , 1982; Dahmann, 1983; Parkes <i>et al.</i> , 2002; Clifton <i>et al.</i> , 2008; Okulicz-Kozaryn & Mazelis, 2018; Garau & Pavan, 2018)
11	Friendly social interactions	(Parkes <i>et al.</i> , 2002; Ross, 2011; Helsley & Zenou, 2014)
12	Mixed uses and diversity of activities	(Baum <i>et al.</i> , 2010)
13	Quality of streets and buildings	(Lynch & Rodwin, 1958; Jacobs & Appleyard, 1987; Smith <i>et al.</i> , 1997; Streimikiene, 2015; Kährik <i>et al.</i> , 2016)
14	Vehicle accessibility	(Lee & Sener, 2016)
15	Pedestrians' accessibility	(Jacobs & Appleyard, 1987; Smith <i>et al.</i> , 1997; Insch & Florek, 2008; Zenker <i>et al.</i> , 2013)
16	Cleanness	(Zenker <i>et al.</i> , 2013; Węziak-Białowolska, 2016)
17	Noise level and air pollution	(Pacione, 2003; Zenker <i>et al.</i> , 2013; Rehdanz & Maddison, 2008; Węziak-Białowolska, 2016)
18	Land and house price compared to other part of the city	(Galster, 1987; Nelson & Saegert, 2009; McDonald, 2012; Streimikiene, 2015)
19	Job opportunities	(Warr, 1987; Room, 1995; Zenker <i>et al.</i> , 2013; Berger-Schmitt, 2002)
20	Bazaar physical condition and its prosperity	(Saraei, 1991; Soltanzadeh, 2007; Habibi & Maghsoudi, 2009; Kasraian & Arshi, 2010; Gharipour, 2012; Pourjafar <i>et al.</i> , 2014)
21	Administrative services (building permits, tax exceptions, construction subsidies, corruption etc.)	(Frey & Stutzer, 2000; Rothstein & Teorell, 2008; Holmberg <i>et al.</i> , 2009; Turró, 2012; Charron <i>et al.</i> , 2014)

Source: Authors.

3.3 Model selection

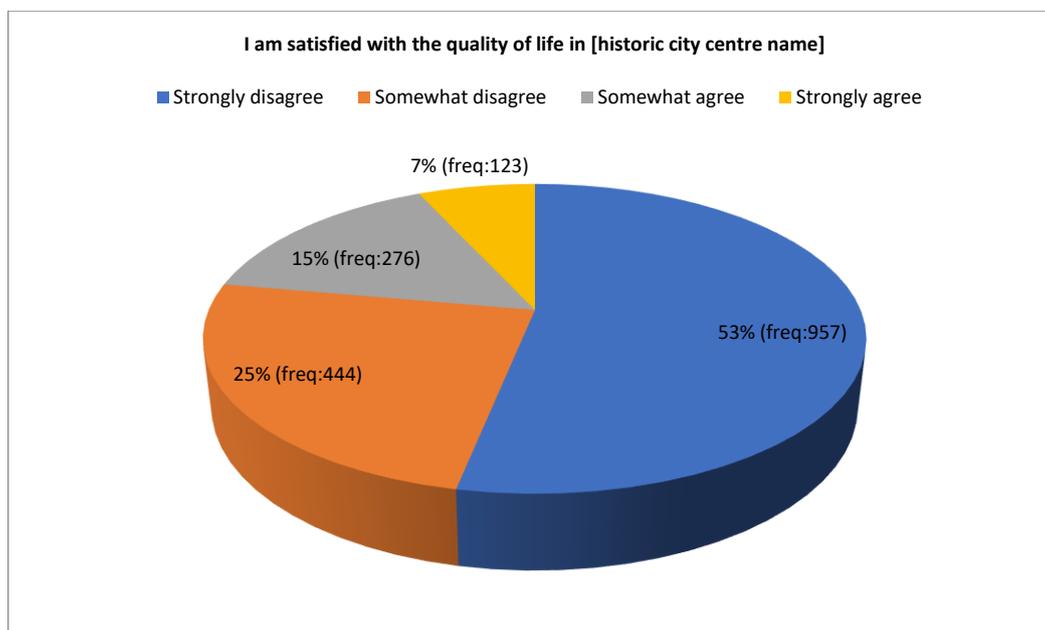
In order to explore the QOL satisfaction in historical city centres of Iran and achieve a predictive model that can express the most important variables based on residents' perceptions, various ML models/algorithms like Logistic regression, K-nearest neighbour, C5.0, Decision list, Bayesian network, LSVM, Tree-AS, Decision list, Random trees, CHAID, Quest, C & R tree and Neural net were examined and, using SPSS Modeler 18.0, the one yielding the highest overall performance in terms of accuracy was selected for this research. Algorithm accuracy was measured through the proportion of accurate predictions. In all cases, 60% of available data were used as a training data set, and the remaining were used for testing (20%) and validation (20%). Partitioning the data in this way allowed to train the model with one sample, test and refine the model using a second sample, and finally validate the outputs with a third set (IBM Knowledge Center, 2020a).

4. Findings

4.1 Survey descriptive results

The results of the survey related to the dependent variable, i.e. satisfaction with the QOL in historical fabrics (used as the dependent variable in the ML model), show that almost 78% of the inhabitants of these fabrics either strongly or somewhat disagree with the statement that "I am satisfied with the QOL in [historical city centre name]" (see Figure 1). Deeper analyses reveal that dissatisfaction with the QOL in the historical city centre of Naeen is higher than other observed city centres (85%), while in Yazd, the QOL dissatisfaction seems lower (73%), which could be due to the restoration measures accomplished in recent years following selection as a UNESCO World Heritage site. However, the actions taken in Yazd have not substantially improved the quality of the resident's life regarding different social and economic aspects. Some physical improvements, which made Yazd centre more a tourist park or a museum than an active urban space for everyday life, have increased the QOL of its residents, but their overall perception of it is almost as low as elsewhere.

Figure 1. Frequencies and percentages related to the dependent variable used in the research



Source: Authors.

Table 3 presents the descriptive information related to the independent variables, arranged according to increasing averages of the ratings given to them (low values indicating poor satisfaction level). It

indicates that respondents are most dissatisfied with access to public transport, followed by vehicle accessibility and bazaar physical conditions. On the other side, they are most satisfied with access to public utilities, pedestrian’s accessibility, and housing prices.

Table 3. Descriptive statistics related to the independent variables used in the research

Descriptive Statistics					
Variable	N	Min	Max	Mean	Std. Deviation
Access to public transport (bus, metro, etc.)	1800	1	2	1.38	.486
Vehicle accessibility	1800	1	3	1.54	.533
Bazaar physical condition and its prosperity	1800	1	3	1.56	.547
Access to sporting and recreational services	1800	1	3	1.59	.622
Friendly social interactions	1800	1	3	1.61	.517
Safety and security	1800	1	4	1.73	.963
Quality of streets and buildings	1800	1	4	1.75	1.053
Administrative services	1800	1	4	1.76	.771
Access to educational services	1800	1	4	1.77	.786
Job opportunities	1800	1	4	1.79	.667
Access to green and public spaces (pedestrian area, playfields, etc.)	1800	1	4	1.85	.803
Access to cultural facilities	1800	1	4	1.88	.873
Noise level and air pollution	1800	1	3	1.95	.701
Mixed uses and diversity of activities	1800	1	4	2.19	.927
Cleanness	1800	1	4	2.21	.762
Access to health care services	1800	1	4	2.56	.999
Access to retail shops and food services	1800	1	4	2.57	.932
Access to mosques and their physical condition	1800	1	4	2.74	1.014
Land and house prices compared to other parts of the city	1800	1	4	2.83	1.019
Pedestrians’ accessibility	1800	1	4	2.97	.972
Access to public utilities	1800	1	4	3.15	.993
Valid N (listwise)	1800				

Source: Authors.

Comparing the results of each case study reveals very similar results in all four cities. Table 4 shows the main variables that had the highest and lowest satisfaction level in every single case. The results show the same pattern in all cases, with minimal changes. This means that the residents of these historic centres have a very similar appreciation of the independent variables that are most representative of their QOL.

Exploring the data disaggregating by demographic groups, the model reveals similar results. In most cases, the four top variables are: access to public utilities; pedestrians’ accessibility; access to mosques and their physical condition; and land and house prices compared to other parts of the city. In contrast, there are some differences by demographic groups with the least satisfying independent variables. A more detailed analysis shows that, for people over 65 years, access to public transport, followed by friendly social interactions, access to healthcare services and public green spaces are among the aspects that were considered to have the poorest quality in the historical area, whilst for the younger age groups (specifically under 30 years), these variables are public transportation, vehicle accessibility, access to sporting and recreational services and job opportunities. Women expressed more dissatisfaction with variables such as safety/security and quality of buildings and streets than men, while on the contrary, job opportunities and bazaar situation were given lower importance scores by men.

Although it was expected that the results of demographic groups would vary based on the level of education, no significant change was observed, although minor dissimilarities could be traced. Compared to illiterate or elementary literate people, educated people were more dissatisfied with the job opportunities and access to educational/cultural services offered by the area.

Furthermore, the level of satisfaction expressed by the educated class in almost all variables was lower than other educational classes.

Table 4. The first and last four identified independent variables in each case in terms of satisfaction

Estilo	The four most satisfying variables	The four least satisfying variables
Kashan	<ol style="list-style-type: none"> 1. Access to public utilities 2. Pedestrian's accessibility 3. Land and house prices compared to other parts of the city 4. Access to mosques and their physical condition 	<ol style="list-style-type: none"> 1. Access to public transport 2. Vehicle accessibility 3. Access to sporting and recreational services 4. Friendly social interactions
Naeen	<ol style="list-style-type: none"> 1. Access to public utilities 2. Land and house prices compared to other parts of the city 3. Pedestrian's accessibility 4. Access to mosques and their physical condition 	<ol style="list-style-type: none"> 1. Bazaar physical condition and its prosperity 2. Access to public transport 3. Safety and security 4. Access to sporting and recreational services
Ardakan	<ol style="list-style-type: none"> 1. Access to mosques and their physical condition 2. Access to public utilities 3. Land and house price compared to other parts of the city 4. Pedestrian's accessibility 	<ol style="list-style-type: none"> 1. Vehicle accessibility 2. Access to public transport 3. Bazaar physical condition and its prosperity 4. Access to sporting and recreational services
Yazd	<ol style="list-style-type: none"> 1. Access to public utilities 2. Pedestrian's accessibility 3. Access to retail shops and food services 4. Access to health care services 	<ol style="list-style-type: none"> 1. Access to public transport 2. Vehicle accessibility 3. Friendly social interactions 4. Access to sporting and recreational services

Source: Authors.

Regarding the dependent variable (satisfaction with the QOL), Table 5 shows the results obtained for different demographic groups.

According to this table, most people in all demographic groups are not satisfied with the QOL and that women, lower age groups and the educated class show more dissatisfaction than other demographic groups.

In contrast, age groups over 65 years, probably due to the deep sense of belonging of the old residents in the area, have expressed more satisfaction than other groups. However, even in this population group, almost 65% of them are dissatisfied with QOL.

Table 5. Results of QOL satisfaction (dependent variable) by different demographic groups

Demographic groups		Satisfied with the QOL (rounded %)	
		strongly/somewhat DISAGREE	strongly/somewhat AGREE
Gender	Male	70	30
	Female	80	20
Age	15-30	85	15
	31-45	75	25
	46-65	75	25
	>65	65	35
Education	Illiterate	70	30
	Some elementary	75	25
	High School	75	25
	University degree	85	15
Marital Status	Married	80	20
	Not currently married	75	25

Source: Authors.

4.2 Modelling results

As already mentioned, SPSS Modeler 18.0 was used to compare the accuracy of the various potential ML algorithms that could be used. Based on the testing data, the results are shown in Figure 2 and indicate that the C5.0 algorithm is the best performer.

Figure 2. Ranking of the reviewed models based on the highest overall accuracy

Graph	Model	Overall Accuracy (%)
	 C5 1	94.809
	 Neural Net 1	90.71
	 C&R Tree 1	88.798
	 CHAID 1	88.525
	 Logistic regression 1	87.158
	 Bayesian Network 1	85.246

Source: Authors

The C5.0 algorithm, developed by computer scientist J. Ross Quinlan as an improved version of its C4.5 algorithm (Quinlan, 2014), is one of the most well-known decision tree models. These models use a new generation of data mining techniques and a class of ML models to explore and extract knowledge from a set of big and complex data and discover predictive patterns (Rokach & Maimon, 2007). They incorporate a decision tree procedure in order to "split the training data set into homogeneous areas where only one iris species is present according to the features given" (Richer, 2020). The C5.0 model works by splitting the sample using as segregator the field that provides the maximum information gain. Each sub-sample defined by the first split is then split again, usually using a different field, and the process is repeated until the subsamples cannot be split any further. Finally, "the lowest-level splits are re-examined, and those that do not contribute significantly to the value of the model are removed or pruned" (IBM Knowledge Center, 2020b).

To implement the algorithm, as mentioned earlier, 60% of the data set was considered as "training data", 20% as "testing data", and 20% as "validation". The C5.0 algorithm has a special ability to improve its accuracy rate by building multiple models in a sequence, a process called "boosting". In this process, as defined by IBM Knowledge Center (2020c): "the first model is built in the usual way, then, a second model is built in such a way that it focuses on the records that were misclassified by the first model and then a third model is built to focus on the second model's errors, and so on". A weighted voting procedure is then applied to the classified models in order to combine the separate forecasts into one overall prediction. The "boosting" process was applied in this research to increase the maximum accuracy rate, which increased from 94.8 % to 97.5 %. Figure 3 shows the first five levels of the final boosted C5.0 algorithm tree (the complete tree is presented in Appendix A). This figure shows the terminal nodes, splitters, and frequency information for every single node.

The exact calibration data and adjustments adopted in the C5.0 algorithm used in our case have been shown in Table B1 in Appendix B. Furthermore, Tables B2 and B3 in Appendix B provide some more useful information regarding the comparison between the data set used in each of the partitions and their predicted actual values by the C5.0 algorithm and the coincidence matrices for different partitions. In these matrices, the rows represent the actual values, and the columns represent the predicted ones. The cells in the table indicate the number of records for each combination of predicted and actual values (IBM Knowledge Center, 2020d).

The results stemming from the decision tree clearly state that fifteen of the twenty-one variables analysed have influential effects on QOL satisfaction in the historical fabrics of Iran. Between these fifteen variables, quality of buildings and streets (45%), safety and security (15%), administrative services (10%) and vehicle accessibility (10%) are by far the most important predictors based on residents' perceptions. Following these four variables, bazaar physical condition and its prosperity, access to health care service, access to green and public spaces, pedestrian accessibility, job opportunities, mixed uses and diversity of activities, access to retail shops and food services, access to educational services, cleanness, noise level and air pollution, and access to sporting and recreational services are among the variables with a certain effect on resident's decisions, but they have very little weight and altogether account for only 20%. In contrast, access to public transportation, land and house prices, access to public utilities, friendly social interactions, access to cultural facilities and access to mosques and their physical condition didn't show any influential effect on QOL satisfaction.

As can be seen, the quality of buildings and streets has a determining role on the QOL satisfaction in these urban fabrics, with a significant difference compared to other variables. According to the data shown in node 1 of the final model (Figure 3), about 92% of residents who were completely dissatisfied (Not at all satisfied) with the quality of streets and buildings would strongly disagree with the term "I am satisfied with the quality of life in [historic city centre name]", and only less than 8% agreed with this term. In contrast, as shown in Node 10, more than 95% of residents who were rather satisfied or very satisfied with the quality of streets and buildings would somehow agree or strongly agree with the abovementioned term, while only less than 5% would disagree.

The decision tree shown is structured by different nodes, each of which provides separate information about the variables and related results regarding the primary target (dependent variable). For instance, node 1 is divided into nodes 2 and 3 based on satisfaction with administrative services. Node 2 indicates that almost 99% of residents who are not at all satisfied with the quality of streets and buildings and administrative services are dissatisfied with the overall QOL in their historic fabric. In contrast, node 3 shows that approximately 85% of residents who were totally dissatisfied with the quality of streets and buildings and were rather unsatisfied, rather satisfied, and very satisfied with administrative services were also ultimately wholly dissatisfied with the QOL in their historic fabric.

Likewise, other nodes can be explained in the same way. It appears that, wherever residents were dissatisfied with the quality of the buildings, as well as with safety, administrative services and vehicle accessibility, they had a negative final opinion on QOL, regardless of other aspects. On the other hand, in most of the cases where residents were satisfied with these variables, they were also satisfied with the overall QOL.

It is noteworthy that, although access to public transportation has the lowest level of satisfaction (Table 3), it has no effect on the decision tree. The same is true for friendly social interactions. As shown in Table 3, residents were not very satisfied with friendly social interactions, but after running the model and analysing the results, it became clear that this variable has no effect on the residents' final decision regarding the QOL satisfaction.

This explains why the presence of construction constraints is one of the most important predictors of QOL. These results of the decision tree outputs, complemented with field observations, allow us to argue that building restrictions have been an important factor in pushing many residents to leave their homes and other properties in old city areas and move to new urban areas with better amenities. This fact exposes the importance of one of the most complex and controversial issues in heritage preservation and in urban fabrics: should they be preserved as they were in the past, i.e., induce their "museisation", or be adapted to revitalise them, even if this supposes to partially destroy some of the assets. This is not debated here, but this research provides valuable inputs to the discussion.

An initial assumption, based on the literature, was that access to health care and education services, as well as to recreational facilities, such as sports clubs and green parks, are of great importance in the QOL of residents. The results presented in Table 3 indicate that residents of historical Iranian cities are not very satisfied with these variables but, when the algorithm was applied, it became clear that these aspects play a minimal role in their final QOL satisfaction. This lack of importance of basic services from the residents' point of view could be because they are accessible in the adjacent neighbourhoods within a short distance of 200 to 400 meters. Actually, residents are more concerned about vehicle accessibility, which ranks fourth in the algorithm outputs. Lack of proper access of vehicles to the old fabrics, due to the narrow alleys, numerous dead-ends and, in some cases, roofed alleys with very low height, affect QOL satisfaction. This is possibly related to poor access for ambulances, fire trucks, cleaning vehicles, etc.

The other important variable affecting QOL in these fabrics is safety and security, which occupies second place in the decision tree outputs. Historical urban fabrics are tackling with plenty of security difficulties due to narrow and dark streets, derelict urban spaces, and abandoned houses, in addition to the lack of commercial activities. Besides, this has attracted asocial activities, such as robbery and drug trafficking, that have added to this insecurity. It is not thus surprising that safety and security is one of the main issues regarding residents' QOL satisfaction. Wherever there are fewer safety concerns, people's satisfaction with QOL is much higher. On the other hand, where many houses and the old bazaar of the city have been abandoned and mostly turned into places for the homeless, such as in Naeen, safety and security concerns are higher than in other surveyed city centres.

5. Discussion

The regeneration of historical fabrics with the aim of improving the QOL of residents has given rise to a great number of studies, plans and projects. In most cases, these efforts have resulted in inadequate or insufficient interventions. Some actions, especially the most visible, such as those on building façades, improving public spaces and renovating public buildings, monuments etc., have been, in general, properly executed, mainly to satisfy global tourism, as in the case of Yazd. However, most of these fabrics continue to struggle with poor infrastructure and service shortages that have ultimately led to QOL decline and resident's displacement.

Our study indicates that public intervention for the regeneration of historic city centres of Iran must adopt an integrated approach if it pretends to preserve their cultural heritage character while keeping them really alive, which means improving their residents' QOL. The main objective of this research was precisely the identification and prioritisation of the factors determining the perception of this QOL to create the conditions for the successful regeneration of these areas. For this purpose, a substantial amount of data was collected. To find patterns and relations in big data sets that simple, routine statistical analyses are not capable to uncover, data mining was used to analyse the data of 1800 residents of four selected Iranian historical fabrics.

As clearly shown in Table 4, the results of the independent variables for each of these four historical fabrics are remarkably similar. This proves that residents' responses to their level of satisfaction using the carefully chosen independent variables are quite similar and that the conclusions reached in this research could be extended to other cities with comparable geographical, economic, social, cultural, and physical characteristics. However, this inference may require further research.

The results obtained from our model reveal that the quality of buildings and streets, safety, administrative services and vehicle accessibility are the most important predictors affecting the QOL satisfaction of residents, while access to public transportation or land and house prices have no effect on their final decision. Comparing the results of this study with similar ones in Iran shows some differences. Habibi (2014), in his research in one of the historical neighbourhoods in Shiraz, identified the quality of the building assets, urban infrastructures and installations and the economic issues as the main factors of QOL. In another study, Poorahmad & Zareei (2015) recognised transportation, housing, city rules, and access to recreational facilities as the most important variable affecting QOL satisfaction in the old tissue of region 9 of the municipality of Tehran. According to Zareian *et al.* (2020), safety, environmental quality, neighbourhood relations, transportation, sense of belonging, physical characteristics of buildings and infrastructure are seven major factors influencing the QOL in the historical fabric of Yazd. In a study about one of the historical areas of Mashhad, easiness to attend religious services, access to daily or weekly shopping centres and access to public transport were identified as the most important predictors of QOL (Khanizadeh & Razvian, 2019).

Despite apparent similarities, the results of the current study are quite different from former Iranian studies. For example, in the last example, special emphasis is placed on religious services as the most important factor affecting QOL in historical fabrics, while the results of the present study did not identify religion as an element affecting it. Alternatively, in another case, access to public transportation was mentioned whilst, in this study, this had no effect on the final opinion of residents. The common factor is the quality of buildings and streets, which has been mentioned in almost all studies.

One of the main reasons for these differences, apart from the specific local characteristics of the different areas, which should always be considered, is the small scale of former studies and the methodologies applied. Most of the methods used in the abovementioned research are based on traditional techniques that do not consider the high correlations among independent variables. The C5.0 algorithm used in our research, apart from being assumption-free, can perfectly manage incomplete or uncertain information and can easily handle multicollinearity issues and present the results graphically without the necessity of computing and interpreting complicated statistics (Chang & Wang, 2006). It does allow for more accurate and reliable results that are largely generalisable. The output of our research could be therefore used as a basis for policymakers, planners, and architects to propose effective actions within holistic regeneration plans that would enhance QOL.

The purpose of this article is not to propose strategies, executive policies or action plans for each of the variables identified in the study. However, the information collected and its analysis seem sufficient to briefly propose some general intervention measures to be considered in these plans:

- 1) The quality of buildings and streets in the historical city centres of Iran is poor. As this was considered the most important predictor of QOL satisfaction, any intervention in these areas should undoubtedly address this concern. Improving the façade and the structure of the buildings and installing sanitary infrastructure, along with ventilation, heating, and cooling systems, are probably the interventions with the most substantial impact. There are, however, irreparable buildings and other constructions in inconvenient places that may have to be demolished, either to build new edifices or to provide additional public space for connectivity or for green/common areas.

Such minimal destruction of the traditional urban fabric, for safety reasons and adaptation to modern needs, is often necessary both to ensure its performance as a lively neighbourhood and, all in all, to maintain the cultural heritage. Regarding the quality of the streets, the fact of putting underground utility lines and, of course, sewerage and renovating flooring and street furniture according to the historical context can significantly enhance public space participation in the regeneration process.

- 2) Safety and security concerns have become one of the main challenges of many cities and of historical centres. Security depends mostly on social factors beyond urban regeneration processes, but there are physical, cultural and social measures that have a direct effect at the local level. Narrow streets, dead alleys, short visuals, etc., characteristic of Iran's historical fabrics, certainly facilitate petty crime and may generate an insecure feeling in people using them. Derelict and uninhabited buildings and poor lighting contribute to this feeling. One of the most important measures to increase safety and security and to generate place-confidence is to have a lively surrounding. This can be achieved by promoting mixed uses and diversity of activities and restoring the dilapidated and abandoned buildings, as mentioned in the first point. Besides being unsafe and creating a negative impact on residents and visitors, they affect the security level, as these ruins are often occupied by drug addicts, criminals and homeless people.
- 3) The rules and laws should be adjusted in line with the real needs of residents, notably on aspects related to the constraints on building permits and land use. Of course, given the value of historical urban fabrics, strong restrictions are needed to maintain their unique character, but if the goal is to prevent the residents' departure and improve their living conditions, the laws and rules need to be adapted to ensure the well-being of residents and improve their living standards, while preserving the precious cultural heritage. In this respect, it would be convenient the development of new by-laws and guidelines by national entities, such as the Ministry of Cultural Heritage, Handicrafts and Tourism, the Ministry of Roads & Urban Development or the Organization of Endowment & Charity, or by city councils and municipalities to facilitate the issuance of building permits. The use of new technologies and building materials should be allowed if it does not damage the original character of the site, and changes in the use of buildings that no longer maintain their former functions, such as public baths or reservoirs, etc. should also be permitted if they do not endanger the traditional social context.
Particular attention should be paid, in this regard, to tourism activities, to avoid the conversion of the area into a soul-less thematic park. The new regulations should also include suitable conditions for land and buildings owners who are expropriated or forced to comply with substantial modifications of their properties. Adequate financial facilities, such as tax exceptions and incentive packages, such as construction subsidies, should be available to encourage people to stay in the historical centre and not to abandon it when their income increases.
- 4) Accessibility and mobility challenges are a particular concern in these convoluted urban fabrics. Although vehicle accessibility is only of fourth importance from the residents' perceptions, it should clearly be the main factor in any regeneration plan, as it requires actions, including infrastructure provision, that is rigid and involve important investments. The provision of minimum conditions regarding vehicle accessibility is linked to the supply of the required public services, such as health (ambulances), security and safety (firemen, police) and collection and delivery services. Good access is particularly needed in circumstances of crisis such as earthquakes, quite common in Iran. On the other hand, attention should be paid to the environmental impacts of additional accessibility. This implies establishing particularly strict regulation measures regarding the type of vehicles allowed in the area and their parking to avoid air and noise pollution and excessive occupation of public space.

The former recommendations should not, however, be considered and treated independently. The regeneration process is a complex and multidisciplinary exercise that encompasses many issues and

must also be addressed from a cross-cutting perspective. A proper approach to the process must include the contribution of various stakeholders and bodies with different roles, coming from different specialities: urban planning, civil engineering, architecture, sociology, statistics, administrative management, financing, etc. In this regard, as Mirzakhani *et al.* (2021) state, besides technical and methodological deficiencies, the absence of an integrated management system in which all stakeholders and bodies pursue a common objective to improve the environment and quality of residents' life is one of the main reasons for the failure of urban regeneration projects in Iran. This presupposes that historical areas regeneration planning, and its implementation, requires pooling the capacities of all participant actors in a concerted action that will finally entice public decision-makers and private investors in the process.

Two all-embracing topics, "integrated governance framework" and "sustainable financing", are inescapable focal points of any regeneration process seeking to enhance the QOL of the residents of historic city centres. These processes require a concerted effort from all stakeholders, both public and private, over a very long period and, therefore, an appropriate and sustained framework of governance and substantial changes in their traditional methods of interaction and partnership. On the other hand, it is impossible to envisage an action to preserve the urban fabric heritage that does not count on financial support from public budgets. Adequate mechanisms to entice private investors whilst ensuring the efficient use of public funds are a major challenge for the implementation of regeneration plans in historic city centres.

6. Conclusion

The quality of life (QOL) in the historical fabrics of Iran has substantially decreased in the past few decades due to many physical, economic, social and environmental problems. This paper provides an insight into these problems through a systematic analysis of QOL satisfaction in historical city centres of Iran and identifying the most important predictors which affect it. For this purpose, several variables selected from the literature search were used in the elaboration of a QOL satisfaction model. Data obtained from a specific survey counting with the participation of about 1,800 residents of old city centres were used to develop ML models that exposed the behavioural patterns of these residents.

The ML algorithm (C5.0) allowed the identification of four significant variables with much higher impact than the other variables examined: quality of buildings and streets, safety, administrative services and vehicle accessibility. The quality of buildings and streets is a factor that had also been acknowledged in other studies in Iran.

However, the results of this study are quite different from those of other studies in relation to other variables. For example, in some studies, access to public transportation, religious shrines, shopping malls or recreational facilities are presented as the most important QOL factors, whilst the results of the present study indicate that these factors have no effect on the final opinion of residents. This does not necessarily mean that they are irrelevant. Present priorities may leave aside factors that could become very important once the more pressing needs are fulfilled. So, critical QOL variables may change in the future, and planners must adopt a long-term view of the subject.

Based on residents' perceptions and technical, social, and political observations stemming from other studies of the authors' line of research, some very general intervention measures have been proposed for each of the main identified factors. Their aim is to help planning the integrated regeneration of historical urban fabrics in Iran but also to implement actions that could enhance QOL and prevent further decline of these valuable heritage assets.

7. Limitations

The geographical scope of this research is limited to the historical centres of four medium-sized cities. Despite the desire of the authors to expand the number of case studies and, of course, the number of respondents, the COVID-19 pandemic and the resulting travel restrictions made it practically impossible. Thus, future studies should explore more cases to provide additional input data to the ML models and obtain even more accurate predictions.

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Authorship

The specific contributions made by each author has been as follows: a) the first author: conceptualization, methodology, software, validation, formal analysis, interpretation of data, investigation, resources, data curation, writing - original draft, writing - review & editing, visualization, revision, supervision; b) the second author: *Mateu Turró*: conceptualization, formal analysis, interpretation of data, investigation, resources, writing - original draft, writing - review & editing, visualization, revision, supervision, and c) the third author: formal analysis, interpretation of data, resources, supervision.

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