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Identifying the physical form of Mashhad based on the analysis of economic trends during 1986-2021

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ABSTRACT

In recent years, the physical form of Mashhad, as the second metropolis of the country, has been affected by macro economic indicators. In order to resist the impulses and pressure of the upcoming economic trends, it is necessary to measure the dimensions and the effect of the mentioned economic forces on the physical form of Mashhad in the past. Therefore The question of the current research is "What is the role of economic trends in the formation of the physical form of Mashhad ?".The approach of the current research is quantitative and a longitudinal survey research method has been used. In order to analyze the trend of economic indicators, the vector auto regression model has been used to measure the effects of variables on each other.Also Landsat satellite images have also been used to analyze the changes in the physical form of Mashhad city.The results of the research show that in recent years, the country's economic developments have led to an increase in the price of currency. This, along with other economic indicators, has caused inflation in the price of land, housing, and rent, and has prompted the city managers to reduce the inflation in land and housing by allowing the growth of Mashhad. The directions of development in the early years were generally in the north and east of the city, but in recent years, the city has expanded to the west and south. The results of the research show that the variables of exchange rate, Gini coefficient and unemployment rate have more stable effects than other economic variables on the physical form of Mashhad city in such a way that whenever one of these three variables is associated with a strong fluctuation, the physical form of Mashhad city is also affected.

Keywords: *Economy, trend analysis, urban form, VAR model, satellite images*

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1. Introduction

Defining the form has never been easy, and for this reason, it is always defined according to its type of use. Its general definition is the pattern of spatial distribution of human activities in a certain period [1]. Kevin Lynch defines the city form as "the physical and visible manifestations of the city" in the book Image of the City. In the definition of the city form, many experts put forward the concept of the spatial pattern of large, immobile, and permanent physical elements in the city, such as buildings, streets, equipment, hills, rivers, and maybe even trees, and use it as a distribution pattern. Space defines human activities at a certain point in time [2]. Hillier (1966) considers the spatial form as the arrangement of components within the whole set. Here, it is assumed that the mass includes the empty space between the buildings. It is not represented in more abstract methods. The main components of Hillier's theory are space/physical form, use/occupation/movement, and perception [3]. Habib (2006) considers the shape of the city to be the spatial and form crystallization of the civic and social life of the city and the activities of urban communities in space and time, which has found a hybrid and trans-two-dimensional nature in a combination of subjectivity and objectivity. From his point of view, the smallest components of this composition are intertwined in the framework of man-made elements of buildings, masses and volumes, urban spaces, open spaces, road networks, squares, and urban facilities as a whole. The natural environment with major elements, such as substrate natural, land and its unevenness, water flows, and vegetation, have a decisive role and influence on how the elements are combined in the shape of the city, and finally, the relationships and the way of the connection of the constituent parts in creating the whole unit and in the connection with the surrounding environment. He introduces the city as a representative of the present time and a bridge between the past and the future [4]. To be able to obtain a complete and correct understanding of the city, one of the aspects that can be investigated is the study of shape and form in the physical dimension. Studying the physical form of the city based on the current situation has a close relationship with the past events of the city and will create insight into the issues, problems, and events facing the city in the future [5].

Although the form of the city, as a container for the placement of urban elements and activities, changes its shape under the influence of values, forces, or various factors, according to the history of cities, one of the most important forces can be considered economic values [6]. In fact, the role of the economy is one of the important factors in the physical form of the city [7]. Today, metropolises, as the most important spatial units of economic activities in modern spatial links, have created vast continuous and discrete territories and have become the axes of economic development circulation around them. Therefore, the physical form of metropolises is constantly evolving and is influenced by currents and relationships that reveal the necessity of dealing with this multifaceted process. In this era, we are facing external motivations arising from the ruling economy, in which personal interests are prioritized over everything, and their effects on the physical form of the city in the form of maximum use of land, showiness of buildings, the existence of mass advertising billboards, and the trend of diverse markets And we see the encouragement of consumerism and... Therefore, the neoliberal strategy has penetrated into the soul and psyche of the cities and caused the physical form of the city to be reproduced in a tight manner under political and economic forces to form an opportunity to facilitate capitalist relations [8]. In general, the economic trends of recent decades in our country have always been accompanied by a sudden increase in inflation, leading to a decrease in the value of the national currency. The result of these developments has been the increase in the price of land and housing due to the influx of investors to the mentioned market to preserve their capital. This rapid process of increasing the price of land and housing has caused the physical form of our country's cities to face many changes. In the meantime, holy Mashhad, as the second metropolis of the country, is not exempt from this rule and has seen huge changes in the field of physical form.

The city of Mashhad, which is the meeting place of more than 3.5 million residents and receives about 30 million pilgrims and tourists annually, is one of the poles of the

country's development. Economic currents have caused the city of Mashhad to face extensive changes in land and housing. The statistics show the rapid development of the physical form of the city, which is currently facing many challenges. In other words, the form and type of development of the urban physical form have been strongly influenced by economic usefulness, and issues, such as livability, quality of the urban environment, respect for the environment, real social participation, etc., have been marginalized. To resist these impulses and the pressure of economic trends on the body of the city, it is necessary to measure the dimensions and the effect of economic forces on the physical form of the city. Therefore, the specific question of the current research is "What is the role of economic trends in the formation of the physical form of Mashhad?" Therefore, the current research aims to "explain the role of economic trends in the formation of the physical form of Mashhad City". In this regard, an attempt has been made to analyze the changes in the physical form of Mashhad City by analyzing the trends of economic flows and measuring the effects of the aforementioned forces on the price of land and housing.

2. Literature review

2.1. Research background

Duranton & Puga (2020) In their article "The Economics of Urban Density", argue that density increases productivity and innovation, improves access to goods and services, reduces typical travel distances, encourages energy-efficient construction and transportation, and provides the possibility of wider sharing of scarce urban facilities. However, density is synonymous with congestion and makes it more expensive to live and move around in cities. They examine the appropriate standard of density and explain how density is the cause and effect of the evolution of cities. Then they address the issue of how urban management should target density[9]. Rodríguez-Pose & Storper (2019) in an article entitled" Housing, urban growth and inequalities: The limits to deregulation and upzoning in reducing economic and spatial inequality", believe that the urban economy and the branches of the mainstream economy - what we call the school of thought We call housing as opportunity - they have argued that the lack of affordable housing in dense complexes is a major obstacle to economic development. In this paper, they argue that many of the claims of the housing-as-opportunity approach are fundamentally flawed and lead to simplistic and inaccurate policy recommendations. According to them, there is no clear and indisputable evidence that housing regulations are the main source of differences in the availability or price of houses in cities. Overall changes in zoning are unlikely to increase internal migration or improve affordability for low-income households in affluent areas[10]. Bogin et al (2019) In an article entitled "Local House Price Dynamics: New Indices and Stylized Facts", have examined the housing price indices of American cities over a 40-year period. They believe that between 1990 and 2015, the gradient of housing prices in big cities will increase, which indicates an increase in the relative desirability of the suburbs [11]. Nikpour et al (2019) in an article entitled "Spatial analysis of housing indicators with a sustainable urban form approach (case study: Babol city)", have come to the conclusion that 36% of neighborhoods have a compact form and intermediate forms and scattered, each covering 32% of the localities. Also, most of the housing indicators in Babol city have spatial self-correlation and have a cluster pattern. The indicators that indicate the desirability of housing are mostly clustered in the compact form, and the indicators that indicate bad housing are mostly concentrated in the middle and scattered form. The obtained results, while paying attention to spatial justice in the expansion and development of housing among neighborhoods, confirm the significant relationship between housing desirability indicators and compact form [12]. Shafiei and Abdi Daneshpour (2018) in the article "Evaluation of residential policy making in the city of Tehran in the face of spatial inequality", focused on the work process as well as the content of policies implemented and effective on the residential structure of the city of Tehran, and identified their effect on spatial inequality. Have. According to them, the agenda of Chirah's policies has a long way to go to face the urban problem of spatial inequality in Tehran [13]. Qalich Khani et al (2018) in an article titled

"Relationships between the factors affecting the housing price and the spatial quality components of the housing", divided the factors that affect the quality of housing and its price into four general categories: physical, economic, social and managerial. , they are divided, the most important of which are in the field of housing economy: design, materials, technology, land price, supply and demand, etc., and the most important components of housing quality are form, connection with nature, layout, accesses, etc [14].

2.2. Theoretical Framework

Urban Housing and Land Economics:

Urban economics examines people's choices regarding scarce resources while households make their choices to maximize utility, and companies make profit maximization the basis of their decisions [15]. In an urban economy, the production and distribution of goods and services are examined not only within a city but also between cities and urban areas [16]. The history of economists' works and research in the field of specific urban markets and urban issues dates back to the mid-1960s. One of the important areas of urban economy is the study of specific urban markets. Among these, urban housing is considered the most important urban market [17]. Both micro and macroeconomic theories are used to solve urban issues and problems. The land and housing market, as one of the major economic sectors, has a close and broad relationship with other economic sectors of every country. This market, along with the two capital and labor markets, are the three main markets that make up the urban economy, while these markets are inseparable and dependent on each other [18]. Urban land and housing economics is the science that examines the land and housing market and the effects of endogenous and exogenous factors on market balance and housing prices and rents. The land and housing market can be divided into the real estate market, in which housing is traded as a shelter, and in the property market, housing is considered an asset and one of the investment options compared to other assets. Housing is a durable and expensive commodity whose value is the land where the building is located [19]. The land and housing economy covers about 20% of the gross domestic product and accounts for more than 40% of the investment [20]. Moreover, the effects of the previous scope and extensive connections with economic sectors and activities and their application in the production and construction process of housing have found a special role and place in the urban economy and economics. As such, it plays a key and determining role in economic growth, investment, cyclical fluctuations, inflation, and income distribution. Therefore, the economy of land and housing has determining effects on economic growth and stabilization and the fluctuations of the national economy. Additionally, it can be effective in the distribution of income, and also through the cost of securing the location of economic activities in the cost of production, as well as the relative advantage of the country's economy in the domestic economy and international trade [19]. Some macroeconomic indicators affecting the price of land, housing, and rent include inflation, exchange rate, unemployment rate, monetary base rate, economic growth, and the Gini coefficient [21],[22],[23].

Urban physical form:

The literal definition of form in the Dehkhoda Dictionary is in the form of shape, face, custom, manner of behavior, template, and example [24]. In the Amid Dictionary, this word is referred to as "shape, shape, state, state, face, appearance, figure, and body" [25]. In the Oxford Dictionary, the form is defined as "the physical and external appearance of an object and the shape of anything" [26], and in the Encyclopedia Britannica, the shape or structure of a thing is defined regardless of its content [27]. Defining the form has never been easy, and for this reason, it is always defined according to its type of use. In urban studies, the form can be considered equivalent to its body. Kevin Lynch defines the city form as "the physical and visible manifestations of the city". In the definition of the city form, many experts put forward the concept of the spatial pattern of large, immobile, and permanent physical elements in the city, such as buildings, streets, equipment, hills, rivers, and maybe even trees, and consider it as the spatial distribution pattern of human activities at a certain point in time [28]. The urban form can be considered a spatial pattern of human

activities. This concept often includes physical features that shape the physical configuration of a city, including the shape, size, density, and configuration of settlements [29]. The urban form also includes the relationship between the physical configuration of a city and the relationships between its constituent elements, such as land use patterns, population and housing density, infrastructure, transportation, and networks [30],[31],[32]. These forms and relationships result from the multidimensional factors shaping a city, including demographic, socioeconomic, planning, and cultural processes that have developed over time and space [33],[34],[35]. The physical form of cities may be unchangeable and rigid, and its characteristics affect and are affected by the dynamics and socioeconomic feedback of the city [36]. In the book "Urban Form Components", Nicola Dempsey defines the term "Urban Form" such that it can be simply used to describe the physical characteristics of the city [37]. Urban form can be considered in different scales. Regional scale refers to the spatial extent of a region and rural-urban configuration [38]. Urban scale refers to the spatial configuration of various types of urban settlements [37]. The district scale refers to the organization of streets and transportation networks and the distribution of urban facilities [38]. The neighborhood scale is related to the configuration of urban blocks [29]. Urban physical form is an aspect that continuously develops in response to economic and technological development and is often driven by planning policies, housing and urban policy, health, transportation, and economics [39],[40]. In Table1 , the components of the urban form are collected based on the theorists' ideas.

Table 1. Components of urban physical form from the point of view of different theorists [41,42,40,34,43,44,45,46,47,48,3,2]

theorist	Components of the physical form of the city
Jatayu et al(2021)	Physical configuration of a city
Al-Saaidy(2020)	Structure, building, block and street pattern
Sharma(2014)	Building density, access to retail and street connections
Schwarz(2010)	Physical structure, size of urban fabric
Kropf (2009)	Spatial relations of physical aspects (site, artefact form)
Bramley (2009)	Size, shape and spatial organization of uses
Cowan(2005)	Structure, granulation, density and appearance
Larkham(2005)	Buildings, streets, squares
Cuthbert & Anderson(2002)	Physical arrangement of activities, households and urban offices and institutions
Conzen(1996)	Buildings, pattern of separate parts and communication network
Hillier(1996)	space/physical form; use/possession/movement; perception
Lynch(1981)	Large and permanent physical elements of the city and the spatial distribution of people in carrying out spatial activities and flows

Based on the review of theoretical literature, macroeconomic indicators (independent variables) affect the price of land, housing, and rent, and the variables of land price, housing, and rent as mediating variables affect the physical form of the city (dependent variable). However, the above-mentioned communication can be imagined in return and in certain cases. Furthermore, sometimes the occurrence of changes in the macro indicators causes changes in the physical form indicators directly (Figure 1).

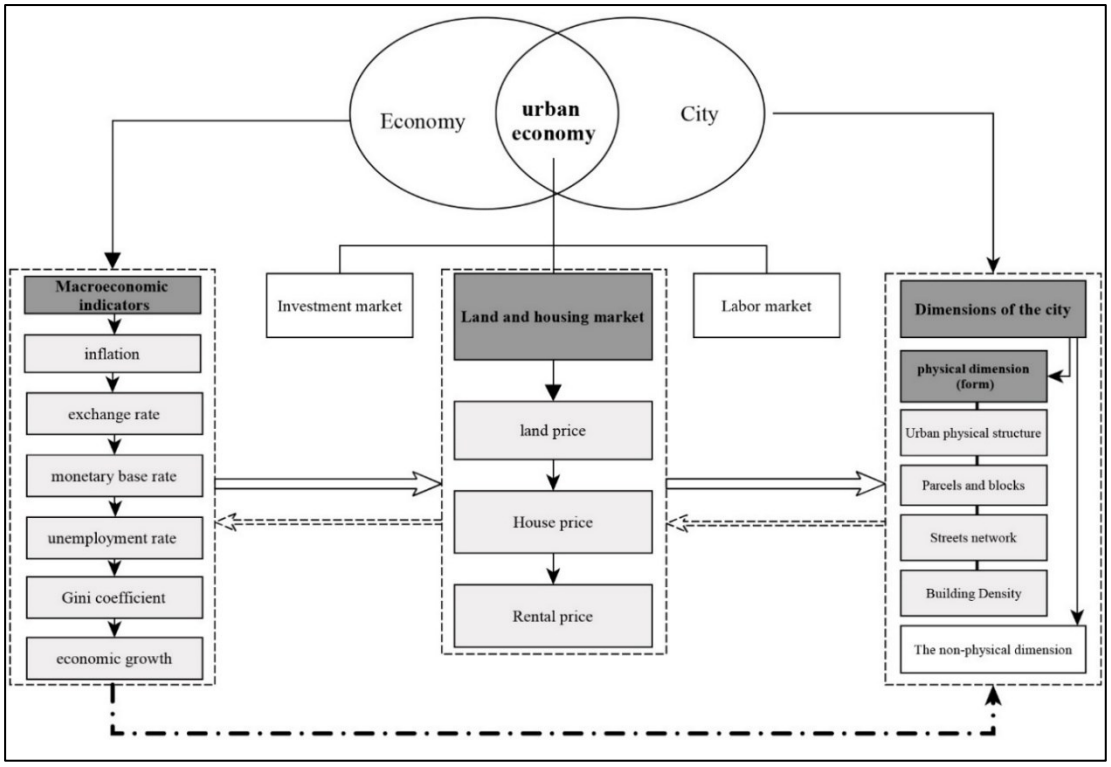


Figure 1. Theoretical framework of the research

3. Materials and Methods

3.1. Methodology

The current quantitative research uses a longitudinal survey research method. Longitudinal research measures the effects of several independent variables on one or more dependent variables over time. In this research, library studies (including statistics of Mashhad city, statistical yearbooks, and urban development plans) and geographic information system data are considered the most important tools for collecting information and as a (historical) trend analysis method to investigate the trend of variables. Economic and physical form changes of Mashhad City during 1986-2021 were used in this study. In the trend analysis method, only the extrapolation of historical data is limited. Trend analysis also has several sub-methods: historical trend analysis, content analysis, periodic pattern analysis, and the use of expert ideas such as Delphi [49]. The trend of economic indicators was analyzed using the vector autoregression (VAR) model to measure the effects of variables on each other. The VAR model is very similar to simultaneous equation models, in which some variables are endogenous and others are exogenous or predetermined (exogenous plus endogenous with a break), but the important issue is that the variables are classified into two exogenous groups and endogenous is optional. In the VAR method, however, we work with endogenous variables, each of which is explained using its past values and those with intervals of other endogenous variables in the model. The use of the term autoregression is due to the presence of an interval value of the dependent variable on the right side, and the term vector is due to dealing with a vector of two or more variables [59],[60]. In this research, Eviews 13 software was used to perform VAR analysis. The changes in the physical form of Mashhad City were analyzed using Landsat satellite images downloaded from the website of the United States Geological Survey (USGS) during 1986-2021. In the first stage of pre-processing, radiometric and atmospheric corrections should be applied to the received satellite images. The purpose of this stage is to eliminate systematic and unsystematic errors present in the raw images. The pre-processing steps of the images, including geometric and radiometric corrections, were performed on the images, and a false color image was prepared by combining bands 3, 4, and 5. In the next step, satellite images were analyzed using the Land Change Model (LCM) in the TerrSet2020

software environment. LCM is designed and built to recognize the land conversion problem and the analytical needs of biodiversity conservation. Land classification requires performing the LCM analysis. In this research, five classes of land were examined in the study area, namely buildings, agricultural land, mountainous land, barren land, and roads. First, the training samples must be entered to perform the supervised classification, followed by the classification of the satellite images. Educational samples were first classified using the maximum likelihood classifier method, the results of which were not acceptable. Therefore, the support vector machine method was used in this research. The accuracy of the classified maps was also evaluated using the error matrix. The data obtained from the auto-regression vector model and satellite processing were analyzed and interpreted at the end.

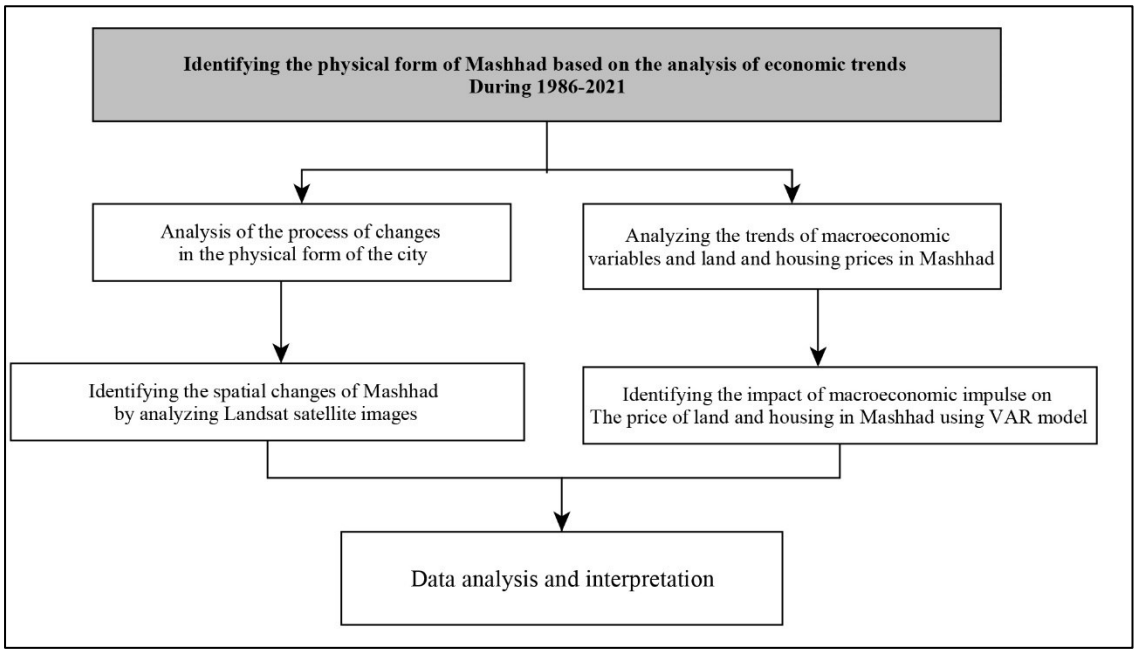


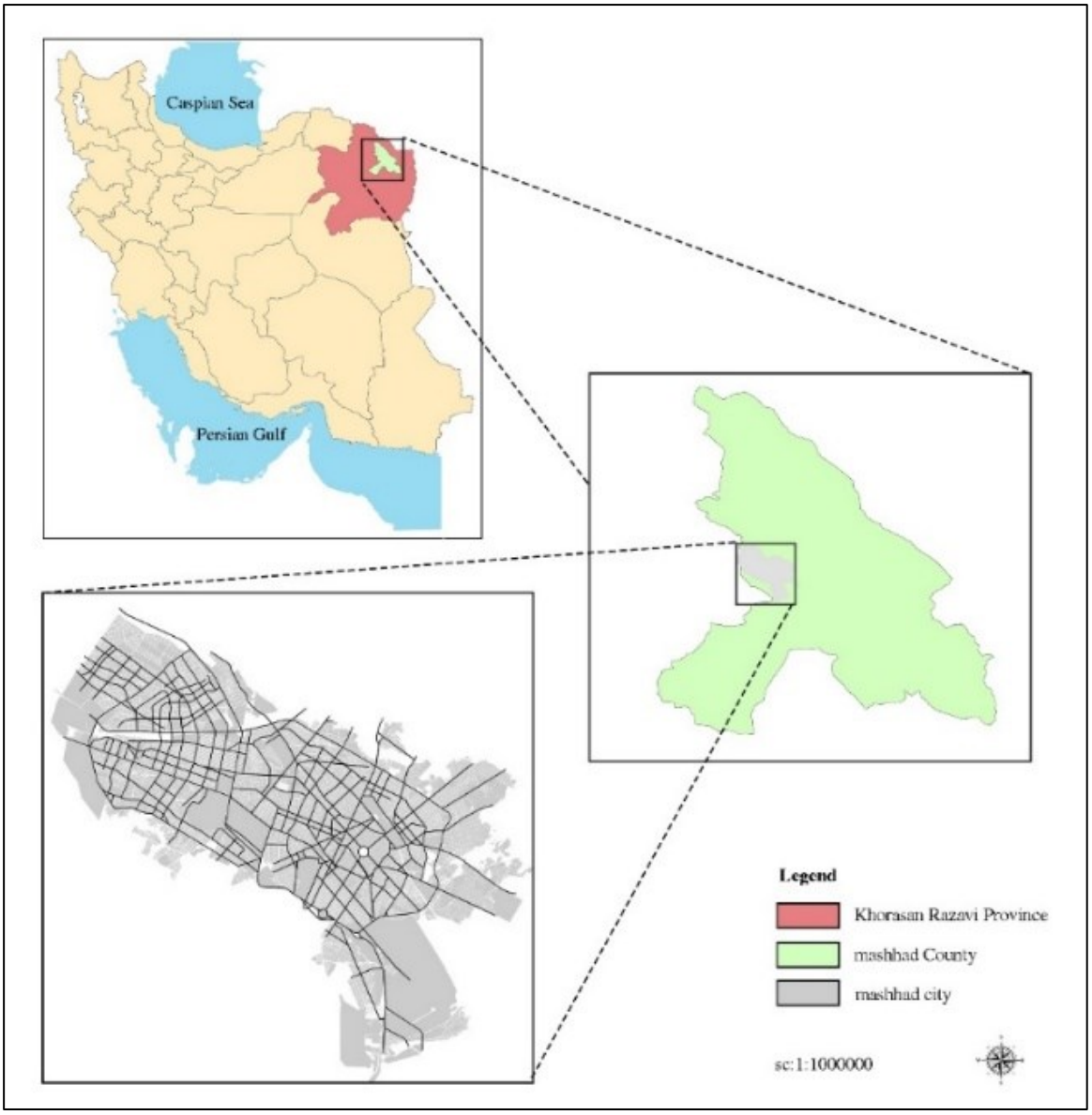
Figure 2. The research process

3.2 Study Area

Mashhad city is located in Khorasan-Razavi province and as the center of Mashhad county with an area of approximately 36147 hectares and a population of 3362242 people. This city is limited to the mountains of Hazar Masjid from the north and Binaloud mountains from the south and west. The height of this city is 943 meters above sea level and the general slope is from northwest to southeast. In the years 1986-2021, the population and the number of households in the city of Mashhad increased by 130% and 262%, which indicates that the size of the household is getting smaller. Also, the population density has grown by 22% from 1986 to 2011, while it has decreased from 2011 to 2021. Net residential density has also grown by 26% in these years.

Table 2. General changes of Mashhad During 1986-2021 [61,62]

Year	size of the city (M^2)	population	Number of households	population density (people per hectare)	Net residential density (people per hectare)
1986	16317	1460005	299534	89.5	364.2
1991	18516	1679861	300317	90/7	369
1996	20762	1908083	412781	91/9	364.5
2001	21243	2196585	434040	103/4	386.4
2006	23331	2427316	637421	104/0	404.9
2011	25696	2807464	815630	109/3	445.8
2016	34345	3057679	930045	89/0	460.9
2021	36147	3362242	1084594	93/0	459.2



Map 1. Geographical location of Mashhad city

4. Results

Changes in economic indicators, including macroeconomic variables and land, housing, and rent prices, as well as indicators of the physical form of Mashhad City during 1986-2021, are discussed in this section.

4.1. The trend of macroeconomic indicators

According to the studies conducted based on the data of the Statistics Center and the Central Bank of Iran, the exchange rate has faced a significant growth from 1986 to 2021, so that the currency (dollar) was 65 Tomans in 1986 while it reached 24529 Tomans in 2021. The obtained data show huge inflationary shocks, especially in 1995 and 2021. Moreover, the exchange rate (dollar) has always been on an upward trend in these years (37636% growth compared to the base year) so that it reached the highest value in 2021. During this period, the economic growth rate reached its highest level of 13.4% in 2016, while this indicator has always had much lower values in other periods. Other economic indicators are shown in Table 3.

Table 3. Iran's macroeconomic indicators During 1986-2021[2] [61,62]

Year	Gini coefficient		unemployment rate		monetary base rate		economic growth		exchange rate		Inflation	
	P	GRP	P	GRP	TBT	GRP	P	GRP	T	GRP	T	GRP
1986	0.3944	-	14.2	-	6062/1	-	-9.78	-	65.00	-	23.7	-
1991	0.3996	9/2	15.5	9/2	12317/9	103/2	-0.88	-91/0	119.6	84/0	20/74	-12/5
1996	0.391	-41/3	9.1	-41/3	47343/2	284/3	6.35	-821/6	175.5	46/7	31/02	49/6
2001	0.3985	56/0	14.2	56/0	97184/8	105/3	2.39	-62/4	175.5	0/0	11.40	-63/2
2006	0.4004	-20/4	11.3	-20/4	279975/1	188/1	5	109/2	921.6	425/1	11.90	4/4
2011	0.375	8/8	12.3	8/8	764568/5	173/1	2.64	-47/2	1053.7	14/3	21.50	80/
2016	0.4046	0/8	12.4	0/8	1798/3	-99/8	13.4	407/6	3031.9	187/7	9.00	-58/1
2021	0.3938	-25/8	9.2	-25/8	4210	134/1	3.12	-76/7	24529	709/0	43.20	380/0

4.2. The trend of land, housing, and rent price indicators

According to the data obtained from the Mashhad City statistics book and the Khorasan Razavi statistical yearbook in the period from 1986 to 2021, most of the housing indicators have generally been associated with significant growth. Due to the increase in inflation and currency rates in these years, there has always been an increasing trend in the prices of land, housing, and rental rates, which have grown by 30182% 74707%, and 49189%, respectively, in these years.

Table 4. Indices of land, housing and rental rates in the city of Mashhad During 1986-2021 [3] [61,62]

Year	Rental rate		The price of one square meter of residential units		The price of a square meter of land	
	T	GRP	T	GRP	T	GRP
1986	72.0	-	8200	-	6115	-
1991	137/5	91/0%	18900	130/5%	15900	160/0%
1996	200/3	45/7%	30500	61/4%	25780	62/1%
2001	512/8	156/0%	86500	183/6%	70900	175/0%
2006	1242/5	142/3%	286820	231/6%	233780	229/7%
2011	2815/6	126/6%	652840	127/6%	394650	68/8%
2016	5571/3	97/9%	1124040	72/2%	517580	31/1%
2021	35488/5	537/0%	6134200	445/7%	1851780	257/8%

4.3. The trend of urban physical form indicators

According to the information obtained in a period of 35 years, the area of Mashhad City has increased from 16,317 hectares to 36,147 hectares, growing by 121.5%, which shows the horizontal growth of the city. In this period, the average dimensions of the parcels were accompanied by a decreasing trend. In 1986, the average dimensions of the parcels were 246.5 m^2, which reached 178.2 square meters (-27%) in 2021. Besides, the length of urban roads has grown by 89.8% due to the increase in the size of the city and the development of car-oriented transportation. During 1986-2021, building density was associated with a growth of 90%, which seems completely normal considering the increase in land and housing prices.

2- P= Percent GRP= Growth Rate Percentage TBT= Thousand Billion Tomans T= Toman

3 - GRP= Growth Rate Percentage T= Toman

Table 5. Physical form changes in Mashhad city During 1986-2021 [61,62]

Year	Length of streets		Floor area ratio of building		average dimensions of the parcels		extent of the physical structure of the city	
	KLM	GRP	Percentage	GRP	M2	GRP	M^2	GRP
1986	393.2	-	114	-	246.5	-	16317	-
1991	450.0	14/5%	124	8/8%	220.9	-10/4%	18516	13/5%
1996	495.0	10/0%	130	4/8%	212.3	-3/9%	20762	12/1%
2001	560.0	13/1%	139	6/9%	205.6	-3/2%	21243	2/3%
2006	629.0	12/3%	145	4/3%	199.5	-3/0%	23331	9/8%
2011	651.5	3/5%	162	11/7%	185.4	-7/1%	25696	10/1%
2016	708.6	8/8%	175	8/0%	180.1	-2/9%	34345	33/7%
2021	746.1	5/4%	205	17/1%	178.2	-1/1%	36147	5/2%

5. Discussion

The stationarity of the autoregressive regression model of the research, and then the analyses of the mentioned model, including the impulse response analysis and variance decomposition for economic variables, are examined in this part. Based on the analysis of satellite images, the changes in the physical form of Mashhad City during 1986-2021 are interpreted in an integrated manner at the end.

5.1. Unit root tests in the vector autoregression model

Before estimating the autoregression model, the stationarity test is used for all time series. If the time series under study is not significant, it is not possible to use autoregressive models due to the occurrence of a false regression problem. Unit root tests are used for the test [63]. In first-order vector self-explanatory patterns, the condition of stationarity is that the absolute value of A1 is less than one. There is a close similarity between this stability condition and the A1 matrix in the first-order self-explanatory vector model [64]. In this test, the stability condition of the VAR model is that all the values are inside the unit circle. Figure3 shows that all the values are inside the unit circle.

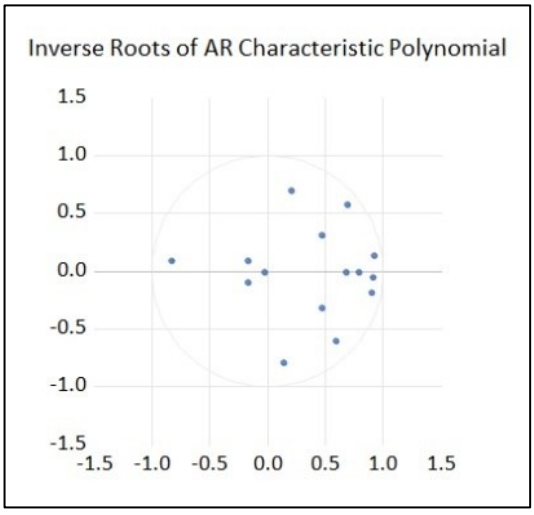


Figure 3. Unit root test of the VAR model

5.2. The impact of macroeconomic shocks on land, housing, and rental prices (impulse-response)

The instant reaction (impulse) examines the effect of one standard deviation of a variable shock on other variables. This estimate shows the effect of a sudden change or shock of one standard deviation introduced by variable A on B in different periods. The occurrence of an impulse resulting from a variable standard deviation of inflation, monetary base rate, and economic growth has caused fluctuations and instability in the price of land and housing, exposing this market to the inflationary

stagnation phenomenon. On the other hand, the increase in the price of the dollar, in terms of the duration of the rise and the scope of growth, has two effects, "short-term inverse form" and "long-term direct form" on various land and housing indices, including prices. By examining 10 periods of exchange rate shock effects on land and housing prices, it can be concluded that a positive effect of the exchange rate is seen on housing prices in the short term (the third period), but this effect is more and even different in the long term in the reverse direction. Based on the trend of currency and housing price fluctuations since 1986, it can be concluded that the high increase in the price of the dollar in the short term has a negative effect on the property market, while the real effect of currency growth on the property market can be seen in the long term. Furthermore, the shock resulting from the standard deviation of the Gini coefficient and unemployment rate variables has caused a sharp increase in land and housing prices and rents.

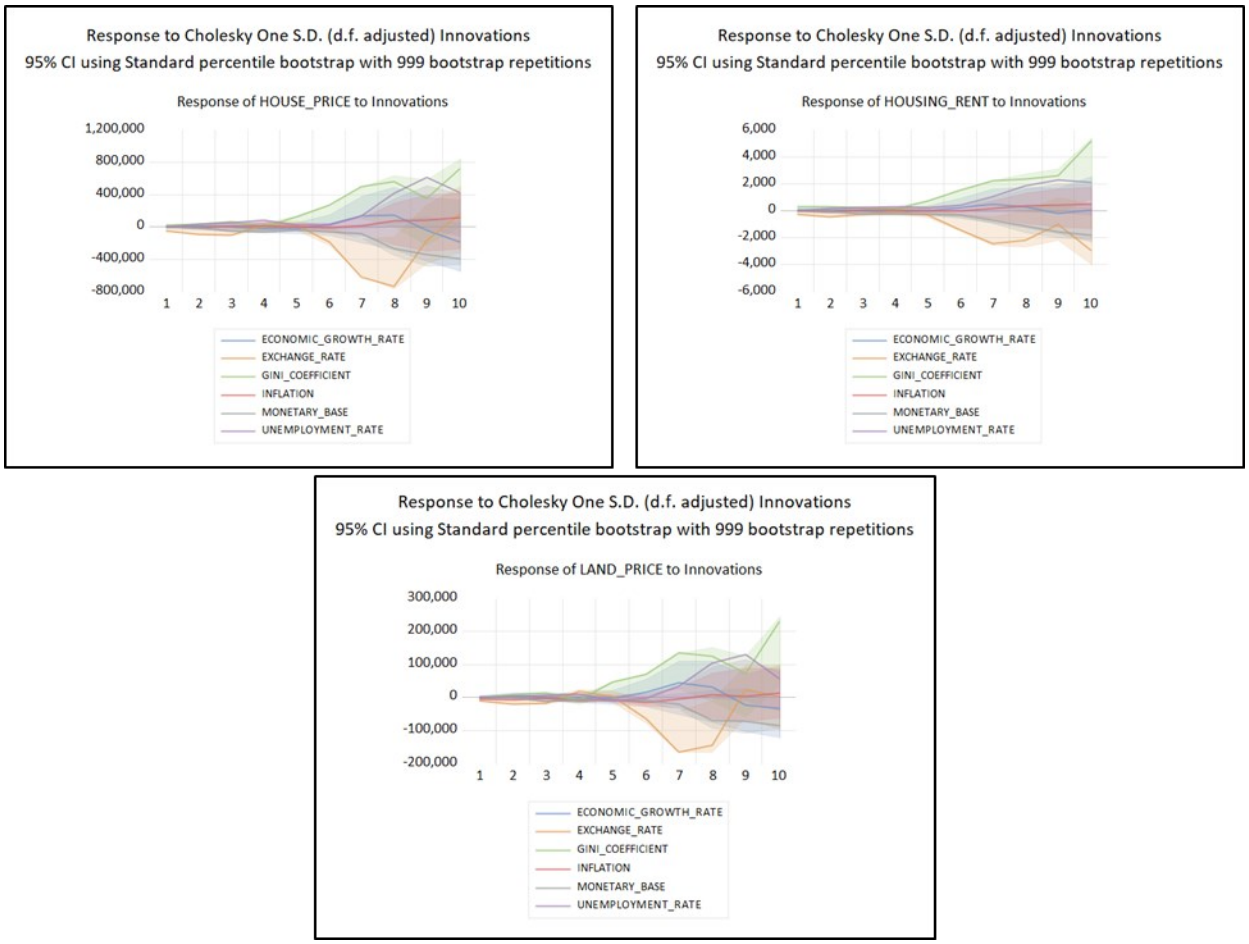


Figure 4. response of housing and rent price variables to impulse of macroeconomic variables in Eviews13 software

5.3. Variance decomposition of land, housing, and rent prices

The variance analysis shows the contribution of each variable in the changes of the target variables. Based on the analysis, inflation and the Gini coefficient have been the most important parameters affecting the changes in the price of land, housing, and rent in these years. In other words, most of the changes in the price of land, housing, and rent have been caused by the increase in the price of currency, as well as the inequality of income or wealth in these years.

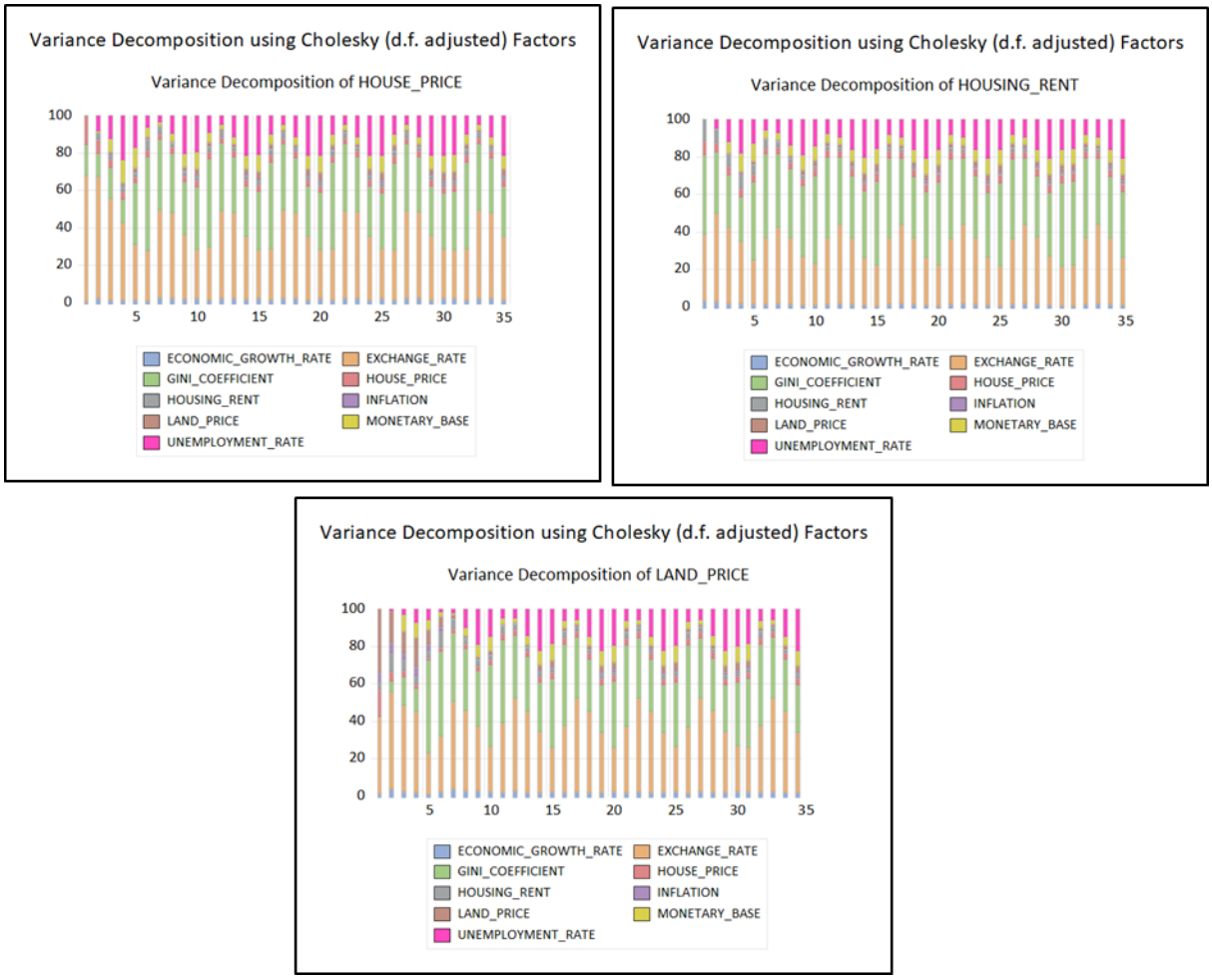


Figure 5. variance decomposition of land, housing and rent prices in Eviews13 software

5.4. The analysis of physical form changes in Mashhad City

During the 1986-1991 period, which led to the end of the war, the country's economy faced various crises due to the special conditions of the war. Due to the special conditions prevailing in the country, the prices of land, housing, and rent in Mashhad City were associated with double growth. Based on the analysis obtained from the analysis of the variance of the VAR model, the main part of the increase in the prices of land and housing was caused by the increase in the exchange rate, the Gini coefficient, and the unemployment rate in those years. Due to the establishment of the construction government, the development of construction activities in the country, and the population growth (15%) in Mashhad, the city witnessed a 13.4% expansion. The important point in this era is the increase of the Gini coefficient and the widening of the class gap and inequalities, resulting in the emergence of marginal centers in the east and northeast of the city. The horizontal growth of the city in this period continued in the same direction, and the pattern of newly built structures was generally organic or irregular. The length of the roads built during this period increased by 14.5%. The average size of the parcels with a 10% decrease reached from 246.5 to 220.9 m^2. Despite the increasing building density, the amount of building height increased with a very small slope due to low construction technology.

During the 1991-1996 period, the exchange rate was associated with a growth of 46%, and the economic growth rate reached 6.35%. The prices of land and housing rose by about 60% in this period, which was less than that in the previous period. The effect of the exchange rate on the prices of land and housing increased until the middle of this period, but the contribution of the Gini coefficient variables, the unemployment rate, and the monetary base rate in land price fluctuations

increased at the end of this period. Moreover, the population of Mashhad grew by 13.5%, which is a lower figure than the previous period. Therefore, the growth rate of the city's area was lower than in the past, and 12.1% was added to the urban area. Still, the direction of the city's growth was toward the east and northeast, and the average size of the parcels decreased by 3% and reached 212.3 m^2 during this period. The pattern of the newly constructed textures was generally irregular and irregular checkerboard similar to the previous era. In this era, a relatively high jump occurred in the density of buildings, with an increasing tendency to build two and three buildings.

During the 1996-2001 period, the most important macroeconomic indicator affecting the price of land and housing, i.e. the exchange rate, did not increase, and inflation reached 11.4%. Despite the growth of most economic indicators, the prices of land and housing jumped by 175% probably due to the resolution of the Supreme Council of Urban Planning and Architecture of Iran entitled "Regulations to prevent the increase in the area of cities" (date of approval 1999). Since the approval of this decree, any increase in the approved scope of the comprehensive plans until the city's gross population density (that is, the ratio of population to the approved area) in the current scope of the plan (that is, the scope of the approved plan plus all possible legal and approved subsequent changes until this date) was prohibited based on the approved plans.

In this era, therefore, a sharp increase occurred in the prices of land and housing, and only 2.3% was added to the size of Mashhad City, which is the lowest rate in all the reviewed years. Furthermore, the population rose by 15% in those years, resulting in an increase in population density to 103.4 people per hectare. During this period, the building density reached 139%, and this period can be called the beginning of the compression of Mashhad City.

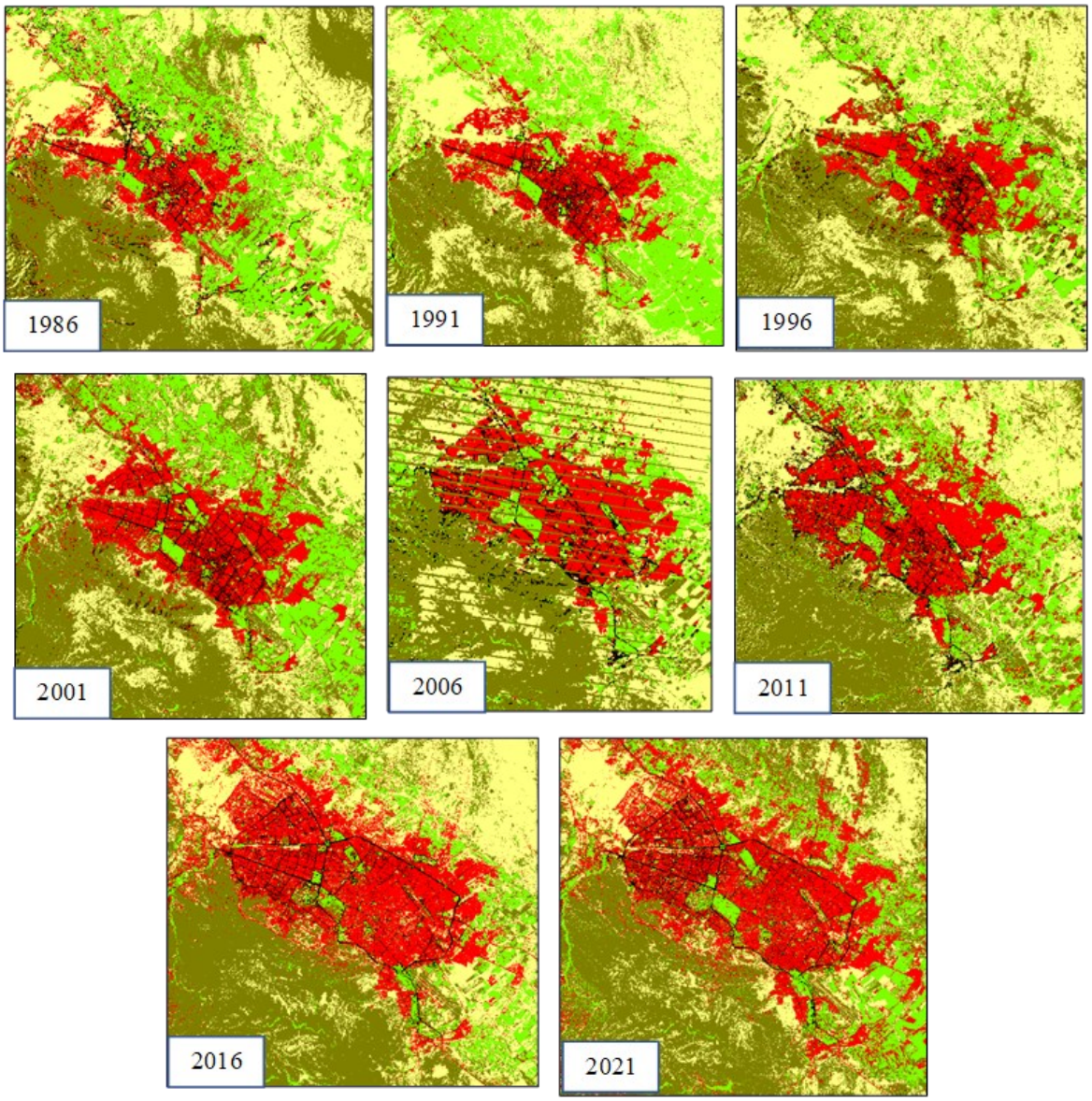
During the 2001-2006 period, the exchange rate was associated with a low growth of 425%, along with increases in the Gini coefficient and class inequalities. The result of these developments was a 230% increase in the prices of land and housing. In this period, the city's size showed an upward trend again, and the unstable situation of land and housing prices made the market currents overcome the political currents of urban management. Besides, the city was associated with horizontal growth, with an increase in size by 9.8%. In addition, the direction of development is from east to west (Qasim Abad), and most newly built structures have a regular checkered pattern. The population of the city was also associated with a 10% growth, and the population density increased to 104 people per hectare. As with the previous periods, this period witnessed a decrease in the average dimensions of the parcels and an increase in the building density.

During the years 2006-2011, the inflation rate almost doubled and the exchange rate grew by 143%. The prices of land, housing, and rent also increased by 68, 127, and 126%, respectively. The population of Mashhad reached 2,800,000 people with a jump of 15.6%. The growth rate of the city was about 10%. The direction of the city's development was toward the west and southwest, and the pattern of newly built structures was regular and irregular checkerboard. The result of these developments was an increase in the population density of the city to 109.3% (the highest level in the years). A decrease occurred in the average dimensions of the parcels along with increasing the building density associated with a 10% growth.

In the 2011-2016 period, the exchange rate increased by 187% along with increasing the Gini coefficient. The prices of land, housing, and rent rose by 311, 721, and 978%, respectively, in these years. A reason for the sharp increase in the prices of housing and rent compared to that of land can be seen in the increased price of construction materials due to the liberalization and the single price of gasoline. In 2014, the price of gasoline was offered at a single rate and free at the price of 1000 Tomans. For this reason, it seems that the size of the city increased with a very steep slope, i.e. 33%, to control the inflation of the housing market and rent. The population also increased by 8.9% during this period. The building density also reached 175%, along with increasing the density of the city, especially in the middle and southwest (new) areas.

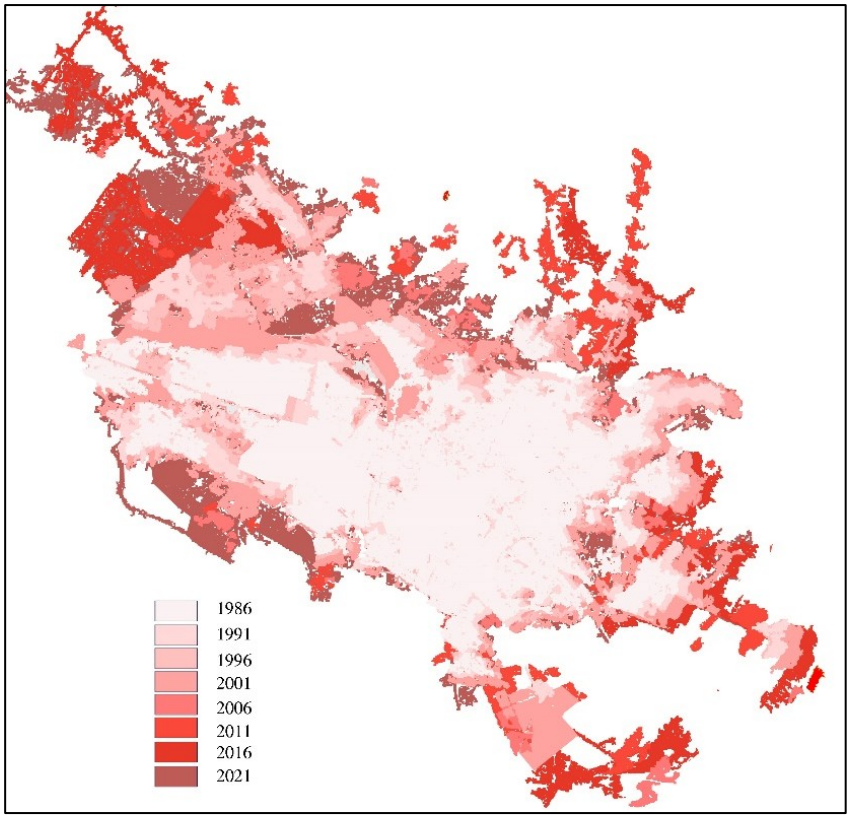
In the 2016-2021 period, inflation reached 43%, and the exchange rate was accompanied by an unprecedented growth of 700%. The

drop in the monetary base rate, the increase in unemployment, and the Gini coefficient showed the chaotic macroeconomic situation. The prices of land, housing, and rent rose by 257, 445, and 536%, respectively, in these years. During this period, the population of Mashhad grew by 9.9%, and 5% was added to the size of the city. The direction of the city's development is still toward the west and southwest, and the pattern of newly constructed structures is regular and irregular. In this period, the amount of building density was also associated with a significant increase of 205%, which shows the greater compactness of the city.



Map 2. Modeling the physical growth of Mashhad in the years 1986-2021 based on the analysis of aerial images and using TerrSet2020 software.

One of the outputs obtained from the processing of satellite images in TerrSet2020 software is the multi-temporal expansion map of Mashhad. Based on the analysis obtained from the period of 2006 onwards, the direction of the expansion of the city was mainly toward the northwest and southwest (Map 3).



Map 3. Multi-temporal analysis of the expansion of Mashhad city in TerrSet2020 software

The review of the economic developments and the physical form of Mashhad City in the last 35 years shows that the exchange rate, Gini coefficient, and unemployment rate variables have had a more stable effect on the physical form. As such, a strong fluctuation in one of these three variables is associated with an impact on the physical form of Mashhad City. Figure 6 summarizes the trend of economic developments and physical form in the last 35 years.

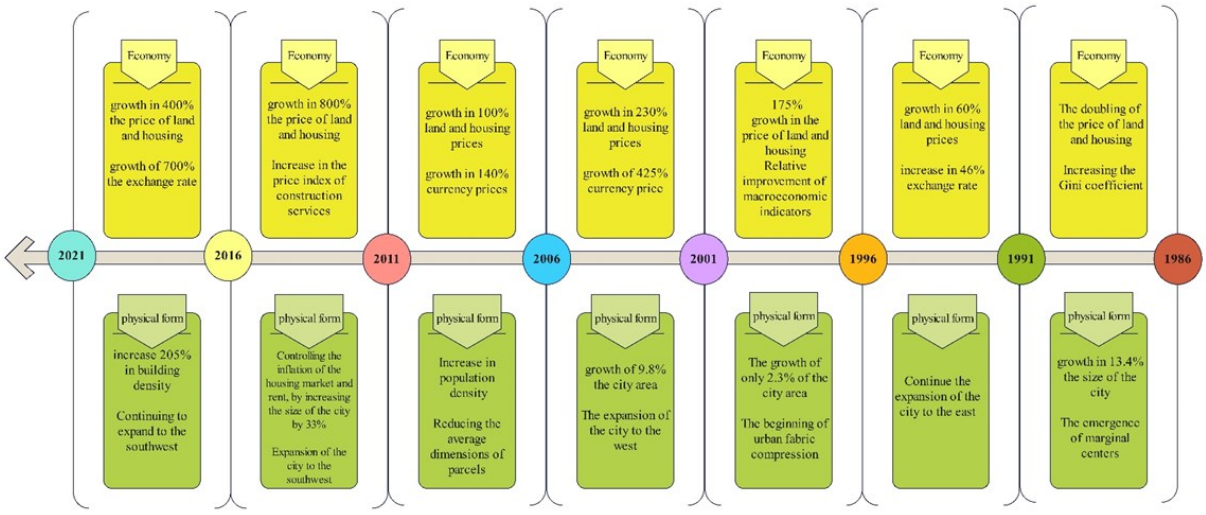


Figure 6. The trend of economic developments and the physical form of Mashhad in the years 1986-2021

6. Conclusion

The present article is an attempt to answer the question "What is the role of economic trends in the formation of the physical form of Mashhad?" To this aim, the trends of macroeconomic data, such as inflation, exchange rate, economic growth rate, monetary base rate, unemployment rate, and the Gini coefficient, were analyzed to measure the effects of the mentioned variables on the prices of land, housing, and rent in the city of Mashhad using the vector autoregression model and Eviews 13 software during 1986-2021. Based on the analyses of variance and economic shocks, the exchange rate, Gini coefficient, and unemployment rate, respectively, are the most important macroeconomic variables affecting the prices of land, housing, and rent. These variables have had a greater and longer impact on the prices of land, housing, and rent in terms of time and share. In the next step, Landsat satellite images were analyzed and processed using TerrSet2020 software to represent the changes and transformations of the physical form of Mashhad City in the mentioned period, and these changes were analyzed from the perspective of economic developments. In general, the country's economic developments have led to an increase in the price of currency in recent years. This, along with other economic indicators, has caused inflation in the prices of land, housing, and rent and has prompted city managers to reduce some of the inflation in the land and housing sector by allowing the city to grow. On the other hand, economic impulses on the household have caused marginalization in the northern and eastern parts of the city. The directions of development in the early years were generally in the north and east of the city, but the city has expanded to the west and south in recent years. The newly constructed textures in the east and northwest parts generally follow an organic and irregular checkerboard pattern, and the new textures in the west and southwest have a checkerboard (regular and irregular) pattern. The examination of statistics shows a weak stream of compression in Mashhad City. In general, this issue is confirmed by the decreasing trend of the average dimensions of the parcels and the increase in building densities.

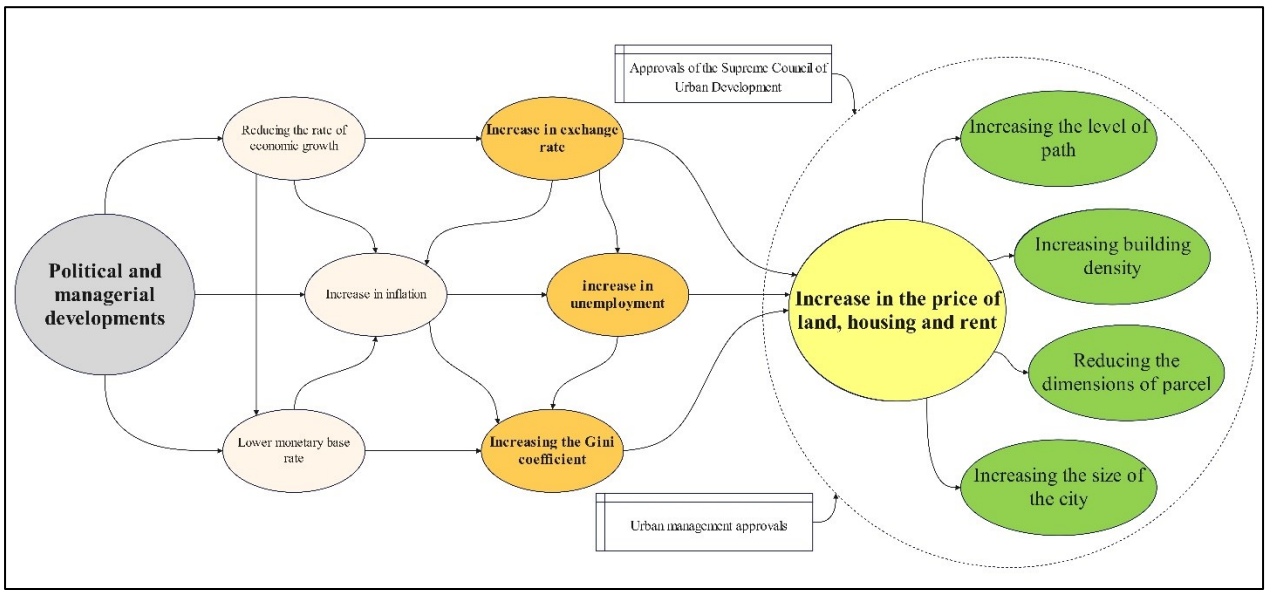


Figure 7. Relationship between economic variables and urban physical form

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