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The Prediction of Tehran City's Sustainable Development Indicators in Iran's 20-Year National Vision (2025 Vision Plan) Using a Dynamic System Modelling Framework*

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ABSTRACT

In recent years, sustainable urban development has been considered more than ever by researchers. Therefore, in the present study, it is attempted to provide a dynamic model of sustainable development for Tehran City. To this end, a computer simulation is applied based on the system dynamics approach using VENSIM software. According to the research purpose and available data, the model is developed using the two socio-economic and environmental pollution sub-sectors. From the results of the simulation in the basic model, the following conclusions can be drawn: (1) The simulation values could well predict the actual values of the variables indicating the sustainable development of Tehran; (2) It can be said that if the same trend continues in Tehran until 2025, the population of Tehran will reach nearly 11 million people; (3) Despite the GDP growth rate considered for Tehran City, the total revenue of Tehran city will increase from 624 thousand billion Rials in 2008 to 315669 thousand billion Rials in 2025; and (4) The amount of carbon dioxide emitted from various uses in Tehran City will reach nearly 100 billion tons per year by 2025, which is very high and it seems essential to adopt appropriate environmental policies.

Keywords: Sustainable Development, Socio-Economic Sub-Sector, Environmental Pollution, Dynamic System Approach.

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1. INTRODUCTION

Any country aims economic development to improve the standard of living and develop cities as the constitutes of each country and an important source of development. According to the UN, 60% of the world's population will live in cities by 2030, leading to extensive changes in lifestyle, land use, and energy demand. Therefore, cities as engines of social growth and development have incredible potential and that is why they should undoubtedly be considered (Amanpour & Mavedat, 2015). In the twentieth century, with the expansion of living in urban areas and the development and growth of cities in developing countries, great challenges have arisen in the socio-economic and environmental areas. All cities, especially metropolises, in these countries, are under poor conditions in terms of environmental health and quality of life, because urban centers are formed by the concentration of people, buildings, and activities, and developed in a limited space. The growth of the global economy, along with the progress of new technologies, has led to the dramatic global development in urban planning and urbanism and thereby making changes in people's living conditions and their environment (Aghabozorgi, Khakzand, & Helali, 2014). The increase of large cities and the spatial effects of their growth have led to the transformation of large rural areas into urban areas and changed the lifestyles in many countries in recent years. In Iran, urban growth has also an accelerating trend so that the rate of urbanization in Iran has reached more than 70% in the years after 2011 according to statistics (Majidi, Zabrdast, & Mojrebi Kermani, 2017).

In recent years, the issues of urban growth, urban development, and urban sprawl and various methods of managing and controlling them have become the important issues related to the evaluation and measurement of urban development plans. In other words, urban growth and specific methods used for managing them have led to mechanisms and conditions in the city that affect many parameters of urban development (Khalili, Zabrdast, & Azizi, 2017).

In recent decades, one of the basic pillars of sustainable development is to achieve sustainable urban development. In this regard, numerous studies and programs have been carried out to find applied principles and solutions in urban development plans, and the idea of sustainable urban development is widely criticized in relation to national development in terms of many aspects. By reviewing the opinions, definitions, and suggestions raised in this field, the sustainable urban development process aims to achieve the sustainability of urban communities. It is a process aiming to create or strengthen the sustainability of the city in economic, social, cultural, and environmental areas. With an emphasis on rational projects, the proponents of urban development try to consider all economic, social, environmental, and physical aspects of plans. It should be noted that to achieve utopia, these sectors must interact. Therefore, considering the importance of sustainability in the development of cities, a wide range of social, economic, cultural, ecological and physical needs must be considered to move towards sustainability and these needs can be defined in terms of urban sustainability indicators.

Environmental problems are one of the most fundamental problems of today's cities and the result of their conflict with the natural environment, because urban development is inevitably associated with the dominance of buildings, industries, transportation network, and economic activities over natural spaces, and this dominance gradually changes to the form of the city's dominance over nature over time and causes widespread urban pollutions, resulting in an imbalance and incompatibility between man and nature and the disruption of ecological relationships. With the expansion of cities, the manifestations and values of the natural environment have been more diminished, urbanites have been deprived of natural attractions, and psychological and social problems have emerged. The concentration of population in cities and suburban areas and improper growth of urban services and infrastructure, especially in developing countries, has made urban areas unsanitary and polluted places facing problems of sewage disposal, sanitary water supply, etc. (Zebardast, 2002; Firoozbakht et al., 2012). The problem planner’s face today is how to implement policies and programs of sustainability and draw the effects of this sustainability. To achieve such a situation, it is required to direct the goals, and executive plans, to reform the status of related structures and to manage affairs. In other words, the other aspects of sustainability are acceptable and high levels of economic growth and employment, social development, and environmental protection. Sustainability is a social development plan seeking to identify individuals' needs, protect environmental resources, and generalize the resulting economic and social resources at all levels (Shieh et al., 2008; Firoozbakht et al., 2012). Therefore, it can be said that providing a model with the ability to indicate and predict sustainable development indicators will be of great importance for economic and social policy-makers. Now, in the present study, using the dynamic system approach, several sustainable development indicators will be predicted for Tehran City. To this end, the present study is organized into seven sections. The second section presents previous studies on the research topic. The third section discusses the theoretical foundations and the fourth section briefly describes the dynamic system approach. The research model is presented in the fifth section and the results of the prediction made by the model and the comparison of them with the real values are presented in the sixth section. In the seventh section, i.e. the final section, some conclusions are drawn.

2. RESEARCH BACKGROUND

Existing studies on this topic can be divided into several general categories. Some studies have presented sustainable development models based on the system dynamics approach, some studies have examined the factors affecting sustainable urban development and some other studies have predicted sustainable development indicators. Now, in this section, considering the existing limitations in this field, those studies close to the present study are briefly reviewed.

In their study, Navabakhsh and Bazrafshan (2014) have studied the sustainable development of Shiraz City in the period from 2001 to 2011. The results of this study indicated that there are direct relationships between the mass media usage, rate of studying, amount of social skills, good governance, ecological behavior, tendency to participate, amount of citizenship rights, leisure time, and amount of social participation indicators and sustainable urban development and they have explained 36% of the variance of the dependent variable (Navabakhsh & Bazrafshan, 2014).

Ebrahimzadeh and Komasi (2014), in their study, have evaluated the quality of municipal services in Sanghar City. The factor analysis of the quality of municipal services, in the form of standard estimation, indicated that the model used for assessing the quality of municipal services was appropriate and all values and parameters of the model were significant. Also, there was a significant difference between citizens' perceptions and expectations in all aspects of the quality of municipal services, so Sanghar City has not been able to satisfy citizens in terms of the quality of municipal services. Moreover, it was concluded that from the citizens' point of view, the five dimensions of the quality of municipal services didn't have the same priority (Ebrahimzadeh & Komasi, 2014).

Amanpour et al. (2013) have examined the development of cities in Kermanshah province from the perspective of utility allocation indices. In their study, eight utility allocation indices were selected and evaluated, including the number of fire stations, number of public libraries, number of public parks, number of public hospitals, number of gas stations, number of universities, number of passenger terminals, and number of communication services offices. The results indicated that there was a significant difference between Kermanshah City and other cities of this province in terms of enjoying utility allocation indices (Amanpur, Alizadeh, & Damanbagh, 2013).

Mahmoudzadeh and Khoshrooi (2015) have investigated the application of logistic regression in modeling the urban development of Bonab City. In this study, they have used satellite images provided in the period 1984 to 2010. After predicting the future pattern of urban development in Bonab city and surrounding villages, the protection of gardens and green spaces strategy was implemented in the urban development process using the map of possible urban development, giving the required space for development and extraction of a natural green belt and proposing a limitation for the development around the green belt, protecting the ecological reserves of Bonab city, reducing the degradation of garden and agricultural lands and controlling the sprawl growth of cities and villages (Mahmoudzadeh & Khoshrooi, 2015).

In a study, Abdullahi (2015) has prioritized sustainable urban development indicators in Kerman City. In this study, which was conducted by surveying seven experts employing in the Roads and Urban Development Organization of Kerman Province and Kerman municipality, the results of the AHP approach indicated that economic sustainability with a weight of 0.703 had the greatest impact on the sustainable urban development of Kerman, followed by social development and environmental development, respectively (Abdullahi, 2015).

Majidi et al. (2017), in their study, have examined the factors affecting the urban growth of Urmia using logistic regression. The results indicated that the most important factors affecting the growth of Urmia City were the proximity to residential areas and roads and areas with moderate population density, respectively (Majidi, Zabrdast, & Mojrebi Kermani, 2017).

Moradi et al. (2015) have studied the requirements for urban development in Boroujerd City. In this study, the Analytic Hierarchy Process (AHP) and Delphi technique were applied. The results of this study indicated that considering the presence of vacant lands, inefficient spaces, and some disturbing industries and the environmental and socio-economic conditions, the worn-out texture of the central part of Boroujerd City can be developed from within. Moreover, it was found that using the abovementioned spaces, the building density and consequently population density can be adjusted in neighborhoods with potential for development from within (Moradi, Parizadi, & Moradi, 2018).

Vermeiren et al. (2012) have examined the effect of economic growth on the urban development of Kampala, Uganda. In this study, considering the annual growth rate of 5.6% in the city, which has led to major social, economic, and environmental problems for the citizens, the urban development map of the study area was extracted using Landsat images taken in 1989, 1995, 2003 and 2010, and then using logistic regression model and considering the higher impact of the layers of roads, access to the city center and distance from built-up areas, three future urban development scenarios were developed to predict urban growth patterns until 2030. The results of this study indicated that the economic growth of this city could affect the urban development indicators (Vermeiren, Van Rompaey, Loopmans, Serwajja, & Mukwaya, 2012).

Zhan et al. (2012), in their study, have developed a model for Tianjin to predict sustainable development indicators. The results indicated that a balance can be established between the three subsystems if only

program policies are used (Zhan, Zhan, Ma, & Chen, 2012).

Using dynamic system modeling, Liu et al. (2012) have predicted the economic growth of Beijing and its environmental impact. In this study, they have considered the main and important components of the model such as city assets, land, capital, population, water resources, economy, and environment. In this study, the dynamic relationships between sub-sectors have been investigated and various drafts have been proposed for policy-making (Liu & Chen, 2012).

Vafa-Arani et al. (2014) have developed a model to simulate energy consumption and environmental pollution in Tehran City. The results indicated that to control and reduce air pollution, increasing technologies in the petroleum and energy industries and developing urban transport infrastructures will be more effective (Vafa-Arani, Dashti, Heydari, & Moazen, 2014).

Xu and Szmerekovsky (2017) have presented a system dynamics model to predict energy savings in the US Food Industry. In this study, they have examined the effects of different policies on energy consumption in this industry in the medium and long term. The results indicated that population growth rate, GDP, agriculture's share of GDP, food waste, technologies, and also agriculture investment are the factors affecting energy consumption (Xu & Szmerekovsky, 2017).

Singh Sisodia et al. (2016) have presented a system dynamics model for India. In this study, using the above model, energy consumption in India has been predicted considering the financial discussions related to investment in renewable and new energies. This study has presented practical policies for the application of new energy resources such as solar energy in India (Singh Sisodia, Sahay, & Singh, 2016).

In this section, several previous studies close to the present study were discussed. The review of previous studies indicates that no system dynamics model for Tehran City, in the framework of sustainable development, has been presented. Therefore, it can be said that the present study is one of the first studies in this field. On the other hand, in the present study, the Value-Added Tax (VAT) is predicted using a sustainable development model, and in this regard, the findings show some innovations.

3. THEORETICAL FOUNDATIONS

The idea of sustainable urban development is one of the extensive aspects investigated in development studies. It is not easy to provide a clear definition in this regard, but it is attempted to explain the meaning of sustainable urban development considering the concepts, principles and history of applied studies. The idea of sustainable urban development is not discussed only in relation to historical developments, but also the wise development of various sciences and social knowledge are discussed. Attention to developments increases the volume and quality of existing knowledge of the urban environment, including the science related to the identification and elimination of air pollution, greenhouse gases, and global climate change and so on. Advances of social sciences also take place with the help of various research agendas on sustainable development.

3.1. Definitions of Sustainable Development and Sustainable Urban Development

Sustainable development is a debatable concept with a wide range of meanings and several definitions have been presented for this concept. The Bruntland Commission's report defines sustainable development as follows:

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. The concept of sustainable development implies limits—not absolute limits- but limitations imposed by the status quo of technology and social organization on environmental resources and by the ability of the biosphere to absorb the impact of human activities."

According to the above definition, sustainable development has three principles: environmental protection, economic development and social development. (Kiani, 2004). According to Leman and Cox, sustainable development is the economic, social and cultural reforms process which is based on technology and accompanied by social justice in a way that does not pollute the ecosystem and does not destroy natural resources.

Sustainable development means to increase human resources, to empower communities to enhance their economic, social, technological, and cultural capabilities. They also believe that sustainable development cannot take place without careful thinking and considering human possibilities. Thus, sustainable development is not an event that happens suddenly. Rather, it is a dynamic and purposeful process that is realized over time and with planning, and aims to improve the level of human life, and requires intelligence, experience, knowledge and creativity (Navabakhsh & Bazrafshan, 2014). Strange (1996) emphasized the respect for human beings, nature, and the environment and referred to sustainable development as development compatible with dignity and nature. According to him, sustainable development involves not only the economy and social occasions, but also the issue of population, the ways to use natural resources, and especially, the effects of these factors on the environment (Strange, 1996; Navabakhsh & Bazrafshan, 2014). Chogol knows sustainable development as development that minimizes the consumption of non-renewable resources. According to Dolein and Yap , sustainable development refers to fundamental changes in ways people think, live, produce, consume, and look at each other (Navabakhsh & Bazrafshan, 2014). In 1990, in

his books " Green Development: Environment and Sustainability in the Third World", Adams stated that the concept of sustainable development could not be well understood in a historical vacuum. To know and understand its challenges, nuances and capacities, it is necessary to consider the changes that have taken place in the thought and practice related to the topic of development, as well as the experiences that led to the formation of this new concept. In such a way, to understand the active and passive aspects and capabilities underlying the concept of sustainable development, it is required to constantly evaluate the criticisms, the path taken, failures and successes, as well as human fears and hopes together. Robert Vogel, who won the1993 Nobel Prize, addressed the relationship between health, and poverty of people of middle-income and sustainable development policies. Vogel said that in developed countries, medical facilities have greatly developed and health and housing policies have been significantly improved, as a result, the ability of manpower to work increases, and economic growth and social development are realized, while in developing countries, problems such as growth retardation, food and financial poverty are the main obstacles to sustainable development (Moldan & Bilarz, 2002; Navabakhsh & Bazrafshan, 2014). The idea of sustainable urban development is one of the extensive aspects investigated in development studies. It is not easy to provide a clear definition for it, but it is attempted to explain the meaning of sustainable urban development considering the concepts, principles and history of applied studies. The idea of sustainable urban development is not discussed only in relation to historical developments, but also the wise development of various sciences and social knowledge are discussed. Sustainable urban development means to enhance land productivity and encourages the reuse of buildings. Given that today the world faces problems such as global warming, excessive energy consumption and unrestricted use of non-renewable resources, and cities are of the main factors causing these anomalies in humans and nature, it is required to adopt principled and trans-regional consumption policies. In fact, those cities owing their sustainability to humility, compassion, and acceptance of the concept of contentment will be viable in future (Bahraini, 1999). The concept of sustainable development also encompasses urban changes and the physical form of the city, and involves issues such as educational, health, and social welfare planning (Mojtahed-Zadeh & Mujtahidz-dah, 1999).

3.2. Sustainable Urban Development Indicators

In general, and according to the provided definitions of sustainable development and sustainable urban development, the following indicators can be considered as sustainable urban development indicators:

1. Economic indicators
2. Trade
3. Economic infrastructures
4. Political and social indicators
5. Level of education and literacy
6. Population
7. Social capital
8. Stability of values
9. Security
10. Public participation
11. Individual and social freedoms
12. Environmental indicators

Now in this section and based on the model presented in the research, some indicators are explained below.

3.2.1. Economic Indicators

Economic indicators include the three domains of 1. Financial indicators such as GNP and balance of payments, 2. Vital indicators for life and natural resources, and 3. Human indicators in the field of economics. In fact, every economic element more or less includes these three domains.

3.2.2. Economic Infrastructures

Economic infrastructure refers to the facilities and installations connecting the city to the rest of the world, such as: transportation (rail, air, road, maritime) and communication systems. These infrastructures must be developed to not prevent the city to participate in the global economy. Telecommunications is considered the basic infrastructure for the 21st century. Similarly, highways were the core infrastructure in the twentieth century. Although telecommunications form the core of modern urban life, the relationship between sustainability and telecommunications has been less considered in the study of urban sustainability. Communications can affect sustainability because of the indirect and complex effects of changes in communication systems on mobility, land use, local decisions, and energy consumption. Telecommunications is truly the central nervous system of the modern cities. Without these communication systems, individuals and firms could not function (Moss & Townsend, 2006).

3.2.3. Political and Social Indicators

Social indicators particularly emphasize education and literacy, employment and unemployment, consumption, income distribution, wealth and health. The desirable and available indicators of this group are including:

- The male and female illiteracy rate;
- Unemployment rate;
- Percentage of population with access to safe drinking water;
- Number of telephones per person;
- Child mortality rate; and
-Level of education and literacy.

Human beings need education and training to become a useful person for society. If a society wants to go

beyond a local community and create democratic participation, education will be vital in this process. Social change and mobility are related to the ability of the education system to equip the population with life skills as well as employment. When the economies of cities become more and more global and the service sector becomes more diverse, jobs become more specialized and, consequently, the need to increase awareness to connect with the modern world develops rapidly. Education provides the necessary structure for progress through the formation of cooperation between various private and public organizations. Education indicators should include formal and informal education. Indicators emphasized in this regard are including school life expectancy (total number of years (full-time or part-time) that five-year-old children can expect to spend for formal and informal education), quality of education (number of people with higher education), in-service education (total training hours provided by employers for workers and employees on an ongoing basis).

3.2.4. Population

According to the United Nations, by 2030, about 60% of the world's population will live in cities, and with the growth of urbanization, especially in developing countries, it seems that in the future we will face an urban world. Cities act as home to about half the world's population. In the United States and other industrialized countries, cities accommodate more than 80 percent of the population. In developing countries, urbanization is taking place with a growing trend through the creation of large urban gatherings such as metropolises. Most of the two billion people that will be added to the world's population are expected to inhabit mainly in the urban areas of developing countries. The current global urbanization and the number and size of the largest cities are unprecedented. The population growth of cities has been formed in most regions and especially in developing countries without considering economic, social and environmental considerations and their natural potentials and limitations. Lack of proper spatial planning, and regional, national and even international imbalances have provided the platform for attracting more migrants to cities, especially large cities, without providing the necessary infrastructure and facilities to accommodate this huge population. The most important factor in the discussion of urban sustainability is population and it's economic, social, environmental and ultimately, managerial effects on cities and even the biosphere. Therefore, it is rational to pay attention to the population as the most important factor in discussing urban sustainability and its indicators. Examining the number of population, its growth rate, migration rate and its impact on the population structure of the city, etc. can be effective in achieving urban sustainability (Gharkhloo & Hosseini, 2006).

3.2.5. Environmental Indicators

The theory of sustainable urban development raises the issues of prevention of urban and district environmental pollution, reduction of local, regional and national production capacities, support for recycling, nonsupport of harmful development and reduction of the gap between the rich and poor. It also emphasizes planning as a way to achieve these goals and believes that governments should provide comprehensive support for the urban environment. This theory examines the relationships between sustainability and urban form, settlement patterns, the effective transportation pattern in terms of fuel consumption and also the city in the urban hierarchy, because it considers the creation of the city only for the pleasure of the urbanites (Scout, 2005). Given that cities are the main polluters of environment and air at the local, national and international scales, recognizing pollutant factors and those conditions exacerbating them in urban environments and trying to reduce them are of necessary measures to achieve urban sustainability. The set of environmental indicators are including:

- Greenhouse gas emissions caused by the use of fossil fuels (in millions of tons per year);
-Average annual population growth rate (in percentage);
- Number of active nuclear reactors; and
- Energy consumption per a million dollars of GDP.

4. THE DYNAMIC SYSTEM METHOD-BASED MODELING

System dynamics, as one of the most important methods of systemic thinking, was first proposed by Forrester (1961) to identify and explain the nonlinear behavior of complex systems and how they interact with each other. He believed that quantitative methods could not solve real-world problems. Because some issues cannot be quantified and the relationship between them is not linear. But this method is able to recognize and explain the relationships between different systems by focusing on the feedback process and determining the causal relationships. In the early 1970s, he used this model to discuss the relationship between different parts of the world in the form of "world1" modeling. The advanced versions of this model, called world2 and world3, were developed and tested on a larger scale in order to examine the challenges faced by human society. This model includes different areas and part of it, which is known as the Industrial National Model, examines the relationship between the industry sector and other sectors (Meadows, Meadows, Randers, & Behrens, 1972). Following Forrester's studies, The Limits to Growth Model was developed using system dynamics. Also, Senge & Sterman (1970) have played a key role in the development of this method. They believed that mental models underlie the idea of system dynamics, and that this learning is reinforced through feedback loops. According to them, the system dynamics model provides the conditions under which

the organization must be constantly learning (Jackson, 2003; Sterman, 2000). Using the system dynamics method, the behavior of US GDP and its effects on other sectors, especially industry, in the period from 1950 to 2000, was modelled and it was concluded that the governing GDP growth pattern of this country was exponential. Accordingly, the industrial sector will grow exponentially with a time lag. Jackson (2003) believed that five factors play a key role in the application of the dynamic system methodology. These factors include definition of the system boundary, development of mental patterns, identification of feedback loops, definition of state and rate variables, and determination of leverage points (Jackson, 2003).

Considering the system dynamics model's capabilities of simulating and analyzing the behavior of complex systems, this model has widely applied in various fields, especially socio-economic systems, over the past few decades. In addition to the above, other scholars such as Hobert et al. (2002), Caridi & Cavalieri (2004), Obloj & Pratt (2005), Senge (2006), Maani and Cavana (2008) were pioneers in this field, and have used in different areas. Since the introduction of this method, more than hundreds of books and magazines have been published in this field and numerous software have been presented in this field. Following these advances, in 1980, the System Dynamics Society was founded at MIT University. This society has been holding annual conferences on the applications of this method in various countries since 1982 (System Dynamics Association Website, 2013).

Considering the various capabilities of system dynamics, today, this unique model is not applied just in a specific sector and various areas use it to model the behavior of systems at the macro and micro levels. In this study, only the specific studies performed in each area are mentioned. For example, the studies by Sterman (2000) in the field of business, Jackson (2003) in the field of management and organizational structures, Walker et al. (2009) in the field of social and management theories, Maani and Maharraj (2004) in the field of decision-making, Quatro and Waldman (2007) in the field of Human Resources management, Galanakis (2006) in the field of organizational learning, Nowell (2003) and Lee (2009) in the field of Health, Wilson (2004) and Allison (2006) in the field of agriculture and natural resources, Li et al. (2012) in the field of environment, Elias (2008) in the field of meteorology, Keegan and Nguyen (2011) in the field of education, Hung (2008) in the field of food security and demographic policy, and Bosh and Nguyen (2013) in the management of complex organizations.

In system dynamics, unlike rational methods, modeling is not a repetitive operation with regular sequence, but also it is a feedback-based process aimed at increasing understanding of the system. Because in fact, based on the feedback received from the model, the understanding of the initial problem increases and leads to the evolution of the model. Simulation models obtain their required information from mental and real-world models and give feedback to change mental models based on the experiences and tests in the model, leading to new structures and decision-making rules. Given that the possibility of experimentation and testing in socio-economic systems is much less than in mechanical systems. Modeling is of great importance in understanding the behavior of the model and the interactions between its components. Therefore, it is required to increase the real understanding of system performance (Ibid, 2000).

In general, the effective variables in system dynamics modeling are including: state variables, rate variables, and auxiliary variables. Separation of these variables is very important in modeling because it significantly influences the modeling results and policies. Figure 1 shows the relationship between these variables. As seen in it, the rate variable affects the state variable based on physical flow while other relationships between these variables are based on the information flow.

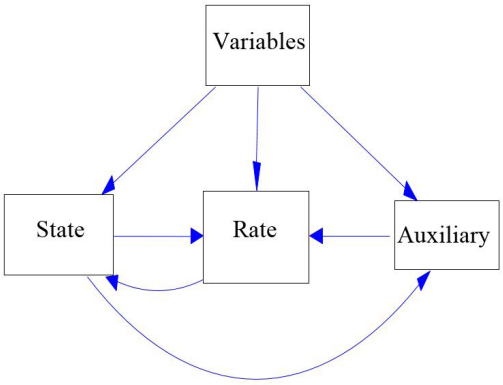

Fig. 1. The Relationships between Variables Used in the System Dynamics Model
(Sushil, 2007)

State variables represent the integration in the system that determines its state at any given time. These variables actually create memory for the system and cause delays through the integration of material or information. Moreover, state variables make the stability and imbalance in dynamic systems by

disrupting the connections between rate variables (input or output) (Sterman, 2000). An inventory of a factory, the balance sheet of an account, the number of employees of a company, or the balance of a bank account are examples of state variables.

Rate variables are those flows entering or exiting the state variable. These variables affect state variables over time. In other words, a state variable can be changed only through its related input and output flows. For example, in an inventory control system, inventory is considered as a state variable that changes with the exit or entry rate of goods from the warehouse and changes the state of inventory of employees with the dismissal and employment rates. In the modeling process, it is usually difficult to distinguish between rate and state variables. State variables are quantities, such as warehouse inventory or bank account balance, rate variables determine the amount of state variables with a quantity in time. In other words, to distinguish the rate variables from the state one, it is adequate to remove the time factor. If the changes in the relevant variable are stopped, this variable will be considered as a rate variable, otherwise it will be considered as a state variable (Ibid, p.23).

Auxiliary variables represent factors determining the relationship between other variables. Auxiliary variables usually include constant and exogenous variables. They are the constant values of those state variables whose rate of change over the time horizon of the model is so slow that they are assumed to be constant. Exogenous variables are those state variables affecting the system but receiving no feedback from the system, so they are outside the model boundary (Ibid, p. 24).

One of the common patterns in time series data is Auto Regressive Distributed Lag. The use of it have several advantages. Above all, all variables do not need to have the same cumulative degree. Also, in this model, in addition to estimation of factors related to the long-term model, an error correction model is provided to examine how to adjust the short-term imbalance to the long-term balance. Pesaran and Shin (1999) showed that estimations using this method for smaller sample sizes (when intervals are well specified) are less biased and more efficient. This approach also makes it possible to investigate the co-integration problem when time series data are not stationary (Piraei & Shahsavar, 2009). The general form of an Auto Regressive Distributed Lag is as follows:

$$y_t = \beta_0 + \sum_{h=1}^{p-1} \eta_h y_{t-h} + \sum_{h=0}^{q-1} \lambda_h x_{t-h} + u_t$$

Where, y_t denotes the dependent variable and x_t is the vector of the dependent variable, and u_t is the white noise. According to the approach presented by Pesaran and Shin, the error correction model can be obtained as follows:

$$\Delta y_t = \alpha_0 + \sum_{j=1}^{p-1} \phi_j^* \Delta y_{t-j} + \sum_{j=0}^{q-1} \beta_j'^* \Delta x_{t-j} + \omega_0 y_{t-1} + \sum_{i=1}^{k} \omega_i x_{i,t-1} + \varepsilon_t$$

Where, k is the number of regressors or the number of elements of vector x_t. In the above model, all of $x_{i,t}$ are exogenous variables. If the factors of $x_{i,t-1}$ and x_{t-1} are significant, co-integration or the existence of a long-run balanced relationship between the model variables is accepted. Therefore, the hypothesis of co-integration test can be expressed as follows:

H_0: $w_i = 0$; i = 0, 1, ..., k

To estimate the ARDL model, the optimal number of lags is first obtained using one of the lag length determination tests (such as Schwartz Baysesian Criterion (SBC), Akaike Information Criterion (AIC) or Hannan Quinn Criterion (HQC)), and then the factors of the following model are estimated.

$$Q(L,P)y_t = \sum_{i=1}^{k} \beta_i(L,q_i)x_{i,t} + \delta W_t + u_t$$

In this equation, we have:

$$Q(L,P) = 1 - \alpha_1 L - \alpha_2 L^2 - \ ... - \alpha_p L^p$$

$$\beta_i(L,q_i) = 1 - \beta_{i1} L - \beta_{i2} L^2 - \ ... - \beta_{iq} L^q$$

Where, L is the lag operator, W is the vector of non-random variables such as y-intercept, trend variable, virtual variable and exogenous variables (Eslamlouryan & Zare, 2006).

5. PRESENTATION OF THE RESEARCH MODEL

In the theoretical foundations section, the sustainable urban development indicators were presented. Now, this section seeks to present a model considering sustainable development indicators, based on the dynamic system modelling. Accordingly, the present research model consists of two socio-economic and environmental pollution sub-sectors, as explained below. Moreover, how to model the variables is described.

5.1. Socio-Economic Sub-Sector

Considering the effect of population and population growth rate as well as GDP per capita on the demand for municipal services, the causal-loop diagram of the socio-economic sub-sector is presented in Figure 2. In this diagram, population, economic growth rate, public satisfaction, value-added tax and demand for municipal services are the main variables of the model. As shown in Figure 2, GDP and public satisfaction can have a significant effect on the value-added tax paid by the resident population in Tehran.

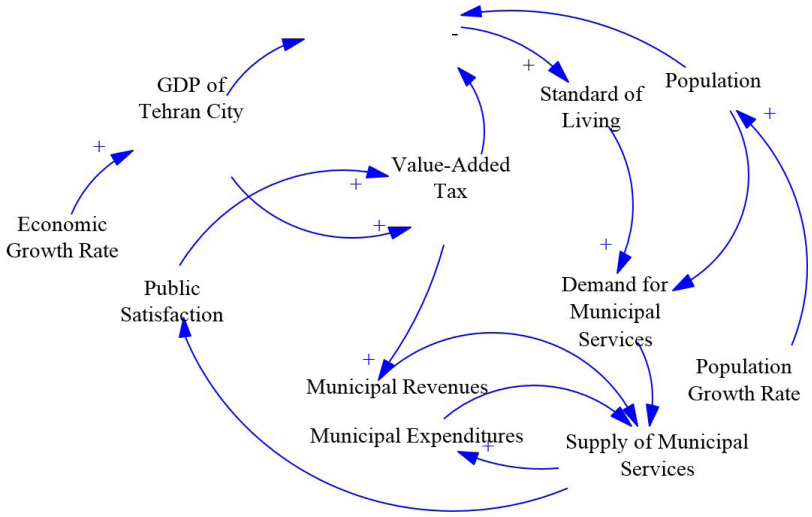

Fig. 2. The Causal-Loop Diagram of the Socio-Economic Sub-Sector

Population is also considered as a reserved (predefined) variable that increases with the average birth rate and decreases with the average death rate. In the model, the average birth rate represents the average birth rate in Tehran during the period of from 2006 to 2014 and equals to 1.96 percent and similarly, the average death rate is assumed to be 0.58 percent. The initial population of Tehran is 8019.7 million according to available statistics and Monsef's study (2009).

To simulate the GDP of Tehran city, this variable was assumed to be a predefined variable that will grow at an average growth rate of 10% per year. This growth rate was obtained according to the growth rate predicted in the 2025 Vision Plan and also the current average GDP growth rate of this city for the period from 2005 to 2013. The initial value of this variable is assumed to be about 624 thousand billion Rials according to Monsef's study (2009). In this study, it is assumed that GDP is obtained from three sectors of industry, agriculture and services in this city. Considering the period from 2005 to 2013, the share of each sector is determined and given in the model.

In the model of this research, according to previous studies, it is assumed that VAT is influenced by the variables of per capita income, literacy rate, VAT rate and also the cumulative costs of municipal services. In the model, the per capita income is obtained by dividing the GDP of Tehran City into the resident population of this city. In the model, the VAT rate is assumed to be 9% according to the last announced VAT rate and the average literacy rate for the period from 2005 to 2013 is assumed to be 98.2% according to the statistical yearbook of Tehran province. The value-added tax function for Tehran City is estimated using the ARDL model as follows:

vaddtax = 1.005e - 16 * gdpper + 1.745 016- * urbanservice + 1.84523e- 16 * litaracy rate - 5.478e - 16 * vaddrate

where, Vaddtax denotes the value-added tax, Gdpper denotes per capita income, Urbanservice refers to the cumulative costs of municipal services, Literacy Rate represents the literacy rate, and Vaddrate is the VAT rate.

Before presenting the simulated values of the cumulative costs of municipal services, it is necessary to explain how the revenues and expenditures of Tehran Municipality are modeled. In the above study and according to the approved budget of Tehran Municipality, it is assumed that Tehran Municipality has eight revenue sources including public tolls with classification No.110,000, special tolls with classification No.120,000, the price of municipal services and profit institutions with classification No.130,000, municipal funds and property with classification No.140,000, donations, gifts and assets with classification No.160,000, tolls and revenues received in the city limits with classification No.170,000, revenues from the transfer of capital assets with classification No.200000, resources from transfer of financial assets with assignment of capital assets 300,000 and value-added tax. The value-added tax was one of the revenue sources with the abovementioned classification numbers but in the present study, it was investigated separately and to estimate the average values of other revenue sources, its value was removed from the total values because the main focus of this study is on it. To consider the total revenue of the municipality, the average values of revenues abovementioned plus the revenue from value-added tax, were assumed as the components of the revenue of the Tehran municipality.

The expenditures of Tehran Municipality are divided into three categories: socio-cultural expenditures with code No.10000, expenses related to the development of urban management and intelligence with code No.6000 and other expenses including traffic congestion costs with code No.20000, municipal services with code No.3000, safety and crisis

management with code No.40,000 and urban planning and architecture with code No.50,000. The sum of the costs abovementioned was included as the costs of municipal services in the research model and it is assumed that people considered theme services provided by the municipality. In this study, the average share of cultural expenses as well as the average share of urban development and management expenses are considered as the share of these expenses from the budget of Tehran Municipality. Also, in order to be close to the realities in the expenditures of Tehran Municipality, it is assumed that Tehran Municipality tries to compensate for the lack of budget by reducing the provision of municipal services when it is facing a shortage of revenue sources. So, the rate of municipal service reduction is estimated by subtracting expenses from revenue yields. On the other hand, the increase in the price of urban services should increase with the increase in population and the increase in demand for these services. It should be noted that the increase in demand for these services was modelled with the population growth rate (birth rate minus death rate), also, in order to reduce the effects of environmental pollution, Tehran Municipality should increase its municipal services, which was also modeled as the costs of reducing carbon dioxide pollution in Tehran City. In summary, it can be said that the cumulative costs of municipal services provided by Tehran Municipality increases with the increase in population and environmental pollution and decreases with lack of budget. The initial value considered for the cumulative costs of municipal services plus the expenditures of Tehran Municipality for the period from 2005 to 2008 is 250 thousand billion Rials.

In order to model and simulate carbon dioxide emissions in Tehran city, energy consumed in three sectors of agriculture, industry and services and the carbon dioxide emission factor (per unit of energy consumed in the abovementioned sectors in Tehran city) were used. In order to calculate energy consumed per unit of production in the abovementioned sectors, the average value-added data in industry, services and agriculture sectors and energy consumed per unit of value-added were used. Also, in order to measure the carbon dioxide emitted in each sector, the factor of carbon dioxide emitted per unit of energy consumed in each sector was used. Data related to this section were collected from the website of the Statistical Center of Iran, the statistical yearbook of Tehran province as well as studies carried out in this field. In this study, it is also assumed that in order to reduce the pollution rate by one percent in each part of the municipality, certain expenses must be incurred, which will be added to the expenditures of Tehran Municipality.

5.2. Environmental Pollution Sub-Sector

With the increase of GDP and production of different economic sectors, energy consumed in these sectors increases, leading to the increase in environmental pollution. On the one hand, this increase in pollution can make it necessary to provide more municipal services in Tehran city, and on the other hand, it can cause public dissatisfaction with the existing conditions. These relationships are shown in the following causal-loop diagram (Fig. 3).

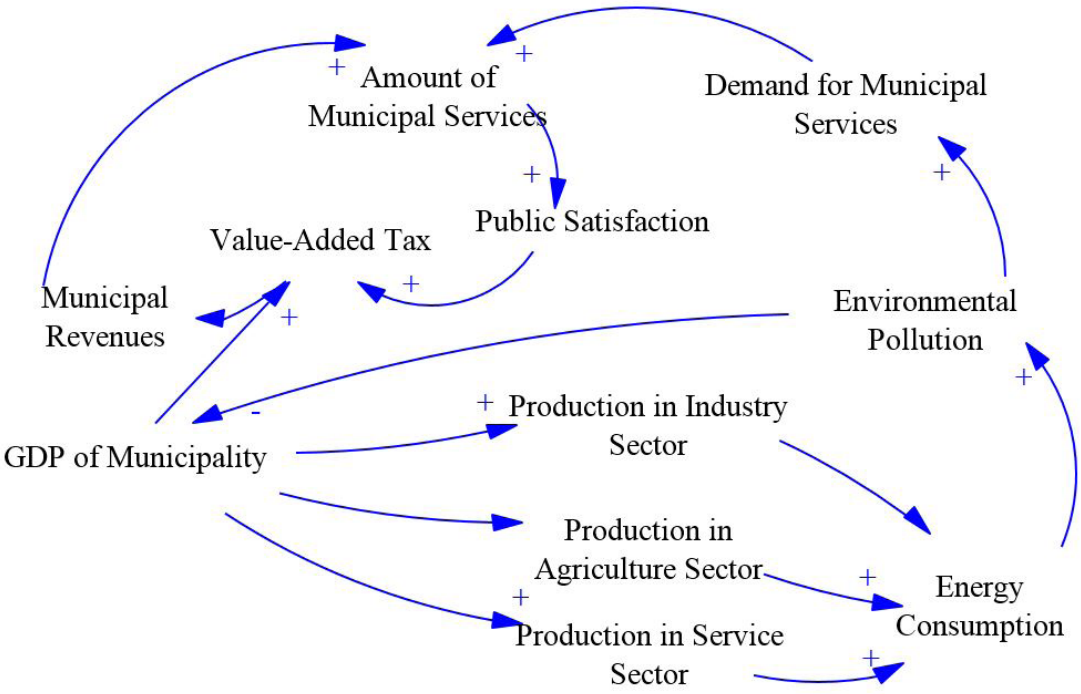

Fig. 3. The Causal-Loop Diagram of the Environmental Pollution Sub-Sector

5.3. Discussion of Research Stock and Flow Diagram

The stock and flow diagram of the socio-economic subsector is shown in Figure 4. The simulated and actual values of the GDP of Tehran City (in one thousand Rials) are given in Figure 6. As seen, the simulated values could predict the actual values of GDP of Tehran City, or in other words, the revenues of Tehran Municipality. The results show that despite the GDP growth rate considered for Tehran City, the total revenue of this city will increase from 624 thousand billion Rials in 2008 to 315669 thousand billion Rials in 2025, i.e. nearly a hundredfold of the current revenue of Tehran Municipality. Of course, it should be noted that in the basic model, the economic growth rate was assumed 10%, which was accompanied by inflation rate. Therefore, the actual revenue, i.e. the constant revenue, cannot be expected to increase by the same amount because part of this increase in revenue will be due to the expansion of the economy as well as the population, and some will be due to the increase in the prices; therefore, by changing the initial assumptions, this value will also decrease. Looking at the current GDP trend of Iran also shows that a hundredfold increase in GDP at current prices has occurred in 2014 compared to 2004. Therefore, the obtained results, in addition to being in accordance with the actual values of the period from 2008 to 2013, are also consistent with the existing realities in Iran's economy.

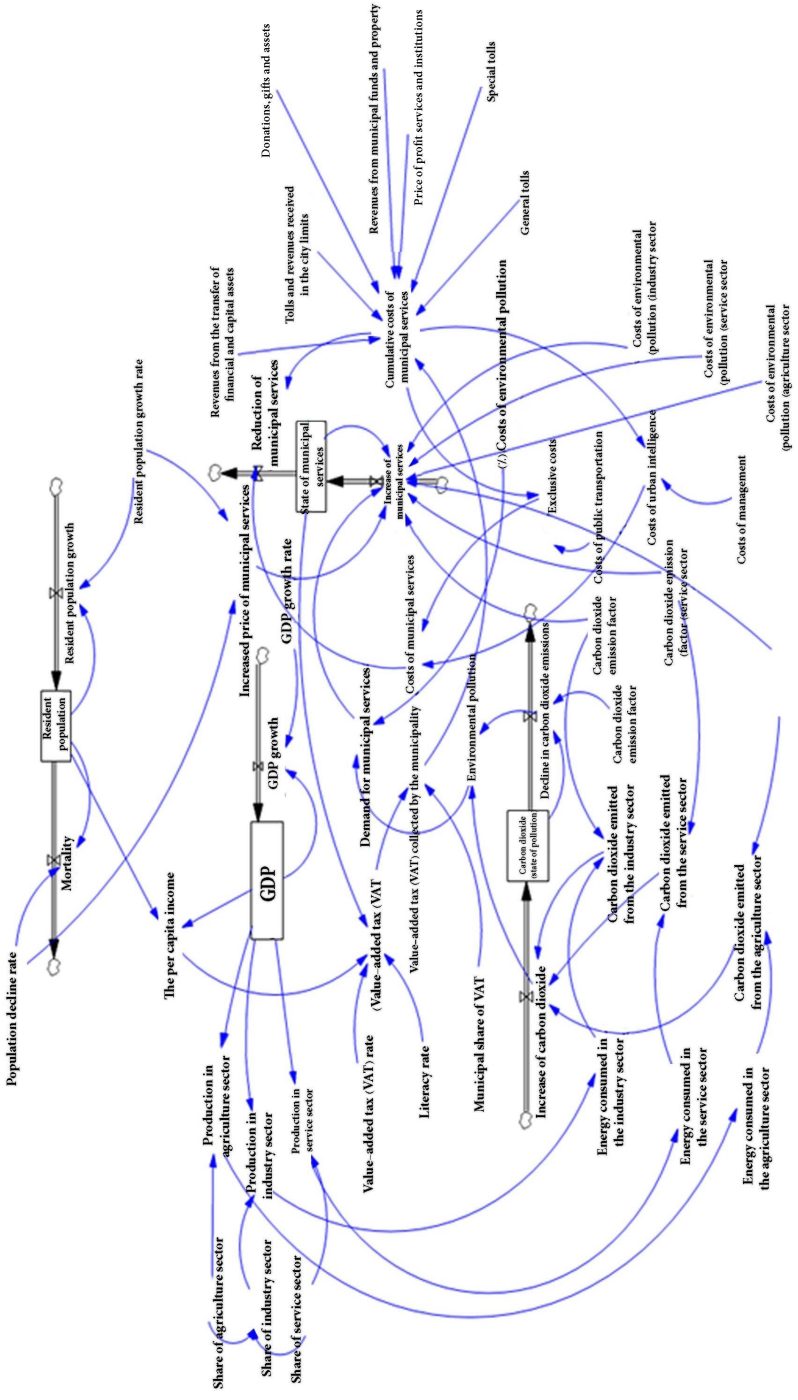

Fig. 4. Research Stock and Flow Diagram

6. THE RESULTS OF THE PREDICTION MADE BY THE PRESENTED MODEL AND COMPARISON OF THEM WITH ACTUAL VALUES

The simulated and actual values of the value-added tax collected in Tehran City are shown in Figure 7. As shown in the figure, the simulation values can predict the actual values of the value-added tax collected by Tehran's Tax Administration. The results also show that with the continuation of this trend, the amount of value-added tax collected from the citizens of Tehran will reach 40 thousand billion Rials in 2025. Now, the values of Tehran's GDP and VAT show that the amount of VAT collected is much less than 9% of the revenue generated in Tehran City. Therefore, it can be concluded that in many cases, the government and the Tax Administration could not collect the actual amount of VAT from taxpayers, meaning a lot of tax evasion in Tehran. The simulation values of the cumulative costs of municipal services are shown in Figure 8. As shown in this figure, the cumulative costs follow an upward trend and will reach about 22 thousand billion Rials by 2025. On the other hand, the results show that the simulated values can explain the actual values of the variables to some extent.

The results related to the costs of municipal services provided by Tehran Municipality are shown in Figure 9. As seen in the figure, there is a slight difference between the actual and simulated values of municipal services costs, which can be attributed to the fact that the budget set in the municipality was based on revenue sources and the model developed in the present study is based on the need and demand for municipal services. So this difference can be rational. On the other hand, it can be said that the difference between the values is not so significant and the simulated values can be trusted.

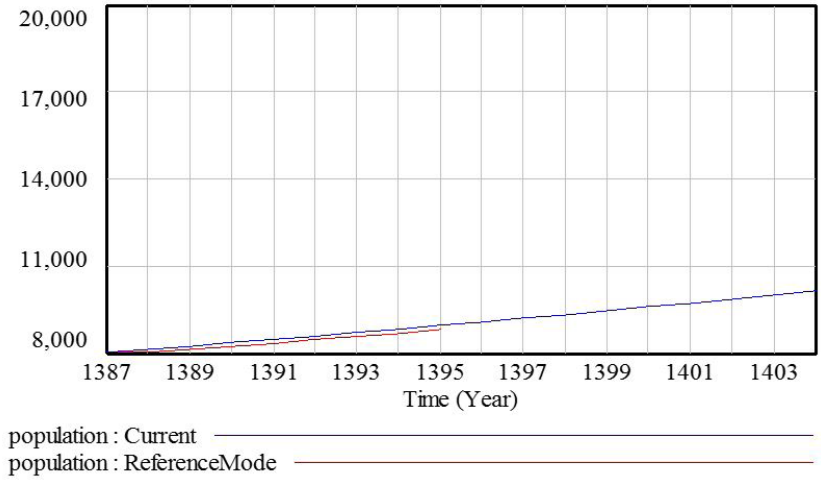

Fig. 5. The Simulated and Actual Values of Tehran City's Population

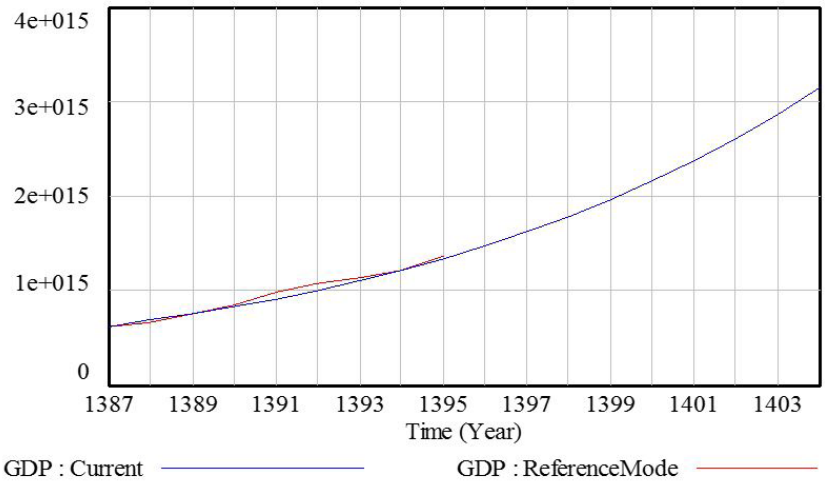

Fig. 6. The Simulated and Actual Values of Tehran's GDP

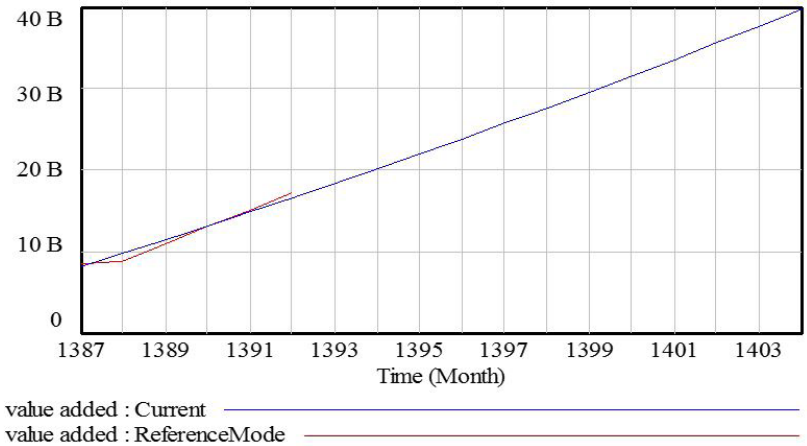

Fig. 7. The Simulated and Actual Values of Value-Added Tax Collected in Tehran City

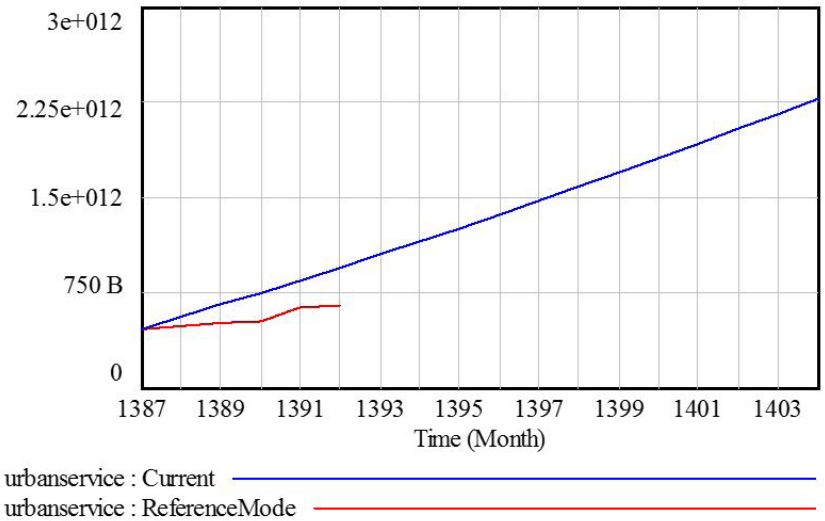

Fig. 8. The Simulated Values of Cumulative Costs of Municipal Services Provided by Tehran Municipality

The simulated and actual amounts of carbon dioxide emitted in Tehran City are shown in Figure 10. As shown in the figure, the simulated values can predict the actual amounts of carbon dioxide emitted in Tehran City. On the other hand, the simulated amounts of carbon dioxide emitted follow an ascending trend, showing that if environmental pollution is not controlled, Tehran City will face a very big problem and by 2025, the amount of carbon dioxide emitted will reach nearly 100 billion tons per year, which will be very high.

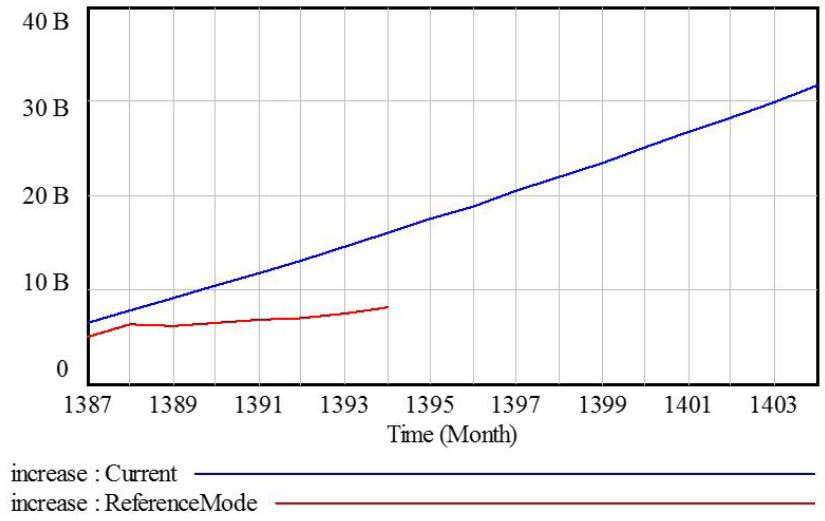

Fig. 9. The Simulated and Actual Values of the Municipal Service Costs in Tehran City

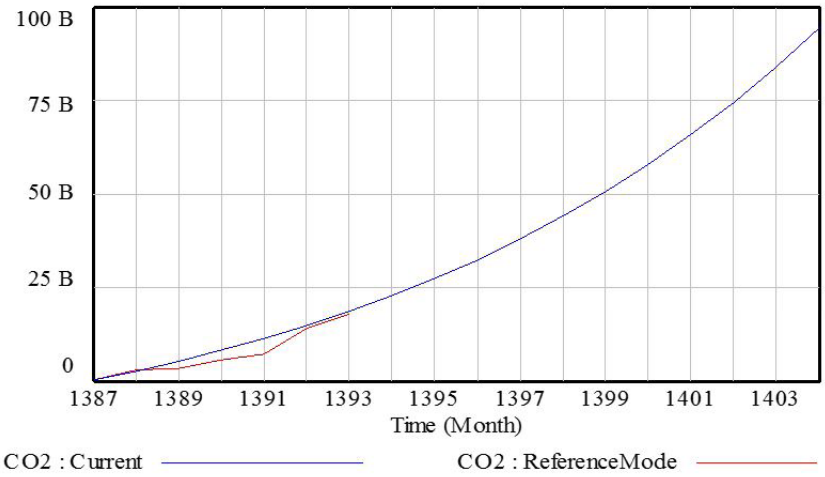

Fig. 10. The Simulated and Actual Amounts of the Carbon Dioxide Emitted in Tehran City

7. CONCLUSION

In recent decades, one of the basic areas of sustainable development has been to achieve sustainable urban development. In this regard, numerous studies have been carried out to find principles and practical solutions and the idea of sustainable urban development has been widely criticized in terms of development at the national level. By reviewing the opinions, definitions, and suggestions raised in this field, the sustainable urban development process aims to achieve the sustainability of urban communities. It is a process aiming to create or strengthen the sustainability of the city in economic, social, cultural, and environmental areas. With an emphasis on rational projects, the proponents of urban development try to consider all economic, social, environmental, and physical aspects of plans. It should be noted that to achieve utopia, these sectors must interact. Therefore, considering the importance of sustainability in the development of cities, a wide range of social, economic, cultural, ecological and physical needs must be considered to move towards sustainability and these needs can be defined in terms of urban sustainability indicators. In recent decades, sustainable development and sustainable regional development have gradually become the new and dominant models in the theoretical and scientific literature common in the field of development and planning. Although these models are differently interpreted, in general, they emphasize the sustainability and continuity of development for all and future generations over time and the all-inclusiveness of the complex economic, social and environmental dimensions of the development process at the level of a country or city. In the present study, it was attempted to provide a dynamic sustainable development model for Tehran City. To do this, a computer simulation was applied based on the system dynamics approach. According to the research purpose and available data, the model was developed using the two socio-economic and environmental pollution sub-sectors. From the results of the simulation in the basic model, the following conclusions were drawn: 1. The simulation values could well predict the actual values of the variables indicating the sustainable development of Tehran; 2. It can be said that if the same trend continues in Tehran until 2025, the population of Tehran will reach nearly 11 million people, i.e. increase of about 2 million people in the next 10 years; 3. Despite the GDP growth rate considered for Tehran City, the total revenue of Tehran city will increase from 624 thousand billion Rials in 2008 to 315669 thousand billion Rials in 2025, and with the continuation of the same trend, the amount of the value-added tax collected from the citizens will reach 400 thousand billion Rials; 4. The cumulative costs follows an ascending trend and will reach about 22 thousand billion Rials in 2025; and 5. The amount of carbon dioxide emitted from various uses in Tehran City will reach nearly 100 billion tons per year by 2025, which is very high.

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