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SUSTAINABLE VERTICAL DEVELOPMENT: A DESCRIPTIVE ANALYTICAL STUDY FOR TEHRAN CITY

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Abstract

Population growth and increase of immigration to big cities challenge the opportunities associated with sustainable develop-ment. Sustainability helps to meet the human developmental goal, and also simultaneously provides indispensable resources and services for economy and society. Through a practical sustainable development, future occupants benefit from a better economy, a rich society, and a healthy environment. Meanwhile, global climate change and concerns about the future redirect contemporary development toward urban sustainability. For this purpose, urban designers and planners can play an important role in a developing city. Their perspectives motivate designers to reinvent high-performance buildings to protect the environment. Their reinvention also affect the ways that a city can operate, as they respond appropriately to demands of inhabitants. In this study, Tehran is studied as a developmental city. For this case, current practice in design, construction, and management of build environment does not properly ensure a sustainable future. Meanwhile, according to United Nations World Population Prospects report, the world population is currently growing by approximately 74 million people per year. Accordingly, population of Tehran in urban region will increase 11 percent in 2025 and 24.5 percent in 2050 comparing to current population size. The maximum population size is projected to reach in 2050. This projection illustrates the importance of sustainable vertical development for this case, and how it could play the primary role for improving economical, social, and environmental aspects of future generations. This paper targets sustainable vertical development for this city, and suggests a practical solution with respect to future concerns. With this aim in view, descriptive analytical approach is considered. Urban sprawl in this city destructs fundamental environment through which the city can breathes. It influences valuable property from economical standpoint, and disturbs social ties between members. On the other hand, vertical development and increase of density in center of urban improve the economical system, strengthen the social tie and protect the environment. For this reason, sustainable urbanism and vertical development are analyzed based on three aspects: economy, society and environment. This study focuses on new urbanism parameters in-volving in urban infill development to cover sustainable development and vertical urbanism, and examines required target for this purpose. It carried out in context of changing regulatory and economic envi-ronment using examples obtained from Tehran. Descriptive analysis suggests that sustainability and vertical developments confronts with possible challenges in terms of environments, which can be covered through smart urban growth.

Keywords: *fill development, Smart growth, Sustainable vertical development, Urbanism.*

I. Introduction

After industrial revolution And fundamentals changes in social and financial components of societies, new and un-expected problems emerged, which were due to surpass of Parastoo Azaram is an assistant professor in Architecture and Urban Planning Department of Payame Noor University, Tehran, Iran (e-mail: p.azaramm@gmail.com). Baharak Pahlavanzadeh is graduated in Master of Urban Planning and Design from School of Architecture and Design in the Shahid Beheshti University. industry and technology over culture of urban planning suit-able with new condition in cities. At this time and also after the twenty century, different standpoints and different designs and patterns were presented for organizing the urban space. Sustainable urban development is one of standpoint that is considered to be one of the important developmental paradigm in the late twenty century [1]. Concept of sustainable development in response to the growth is being considered as a new understanding of world challenges like environmental and developmental issues associated with

human activities, population growth and variation of political structures [2].

Urban area are the primary location for human activities, and also they are the major consumer of natural resources. Therefore, achieving the highest rate of sustainability in cities plays a crucial role. Sustainability in urban area is not only about environmental issues but also it affects economic dy-namics, residential area and social equality. Development is identifying a qualitative concept determining quality of life including education, healthcare, prosperity, freedom of speech, human rights and so on.

According to the United Nation's report in 1900, only ten percent of world's population were living in cities. However, world's urban population reached to fifty percent in 2007. It is expected that 5 million people until 2025, and 7 million people (e.g. 75%) until 2050 are living in urban area [3].

Growth of city space in response to corresponding popula-tion can be in form of horizontal growth, physical growth, or vertical growth. Each of these forms impose different frame-works. Among them, physical growth emerges by increase of urban area, or in form of horizontal growth. However, vertical growth works by internalization of population and compression of urban patterns. These patterns lead to different consequence and results depending to types of the growth in urban area.

In this paper, development principle that matches suitably with principle of urban sustainable development is considered. Patterns of urban development is dealing with ground which is one of the limited sources for human activity, so it is being considered as one of the important subject of sustainable urban development. Arguments around proper form for a city are clarified through compaction and sprawl which is between centralization to decentralization. In general, two main the-ories are being considered for citys form and sustainable development. In the first theory, cities can be directed toward sustainable development through compaction of cities and increase of density together with implementation of mix-use. On the other hand, the second theory implies sustainable urban form can be achieved through extensive development and slight density. Based on this theory, low-density urbandevelopment, low-rise development or widespread city are theorized. Some studies properly consider goals of sustainable development well-matched with compact cities.

The center of Tehran province is Tehran city which is the first metropolis in Iran. This city includes 22 districts. Due to its political, commercial, and cultural roles in addition to its growth and industrial development, this city experiences considerable physical changes. According to the statistics obtained in 2011, this city is the biggest city in the west Asia and is ranked 42nd biggest city in the world. Population density is estimated between ten thousand seven hundred to more than eleven thousand person in kilometer. According to statistics, Tehran is ranked 20th in the world based on populations density. The administrative structure of Iran is organized in Tehran. In addition, this city maintains half of the industrial activity. Therefore, according to the modern standpoints in urban development and maintaining principles of sustainability and especial features of Tehran metropolis, strategies and guidelines for improving the quality of this city in the future can be suggested through studying physical growth of the city and its compliance with the principles of sustainability.

In this study, target is studying the impact of two issues: vertical development as of a way for urban growth and sustainable development. Therefore, these issues initially are being studied separately and then in combination. Eventually, studying the Tehran case illustrates the relation between these issues.

Ii. Theoretical Fundamentals

A. Sustainable development

1) Sustainability concept: Sustainable development is de-fined as a way of satisfying requirements without damaging the ability of future generation. In this definition, rights of every generation for having natural resources the same as the other generation is being recognized, and use

of natural resource is authorized proportional to the advantage. According to the Brundtland report and its definition for sustainable develop-ment, some of the key extent and purpose of sustainable development mentioned in literature and documents are:
Equality between generations
Inter-generational equity (including social and longitude equality)
Protecting of the natural environment (living within the nature capacity and stable ecosystems)
Minimal use of non-renewable resources Economic sur-vival and variation (proportionality between work and income)
Standalone community (social unity)
Individual welfare (provision of basic needs for members of society)
Sustainable urban shelter (proper housing and affordable for all)
Sustainable urban access (mobility and protection of resource)
Sustainable urban life (providing habitable city)
Sustainable urban democracy (citizens empowerment)

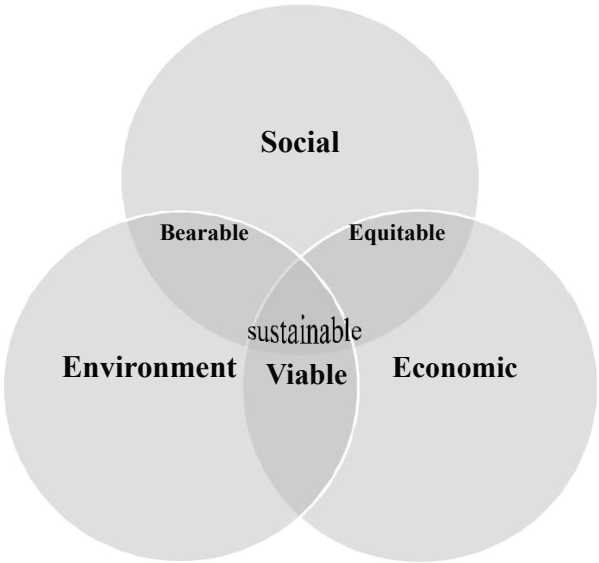

Fig. 1. Schematic Sustainability Concept

Studying primary features of sustainable development is a proper guideline for stepping in its implementation. Therefore, investigations related to sustainability are in close relation with two major questions about the content of sustainability and its indicators. In literature, sustainable development is being studied in different aspects including economy, social, eco-logical, institutional, moral, political, and so on. Diversity in applied investigations is due to complex nature of sustainable development [4].

Concept of sustainable development can be studied from different scientific standpoints [5] as demonstrated in Figure 1.

Economy: development that guarantees averages for in-come for the future generation is higher than the current generation.

Society: development that is produced from concept of society for example protects social relations.

Environment: development that guarantees preserving biodiversity, ecosystems and environmental process.

The economical aspect is based on Hicks-Lindahl maximum income and Solows (1974, 1986, 1993) capital convertibility theory. This theory indicates providence in use of resource for the benefits of future generation. Economical sustainability for maximizing the income is based on the minimal and optimal consumption of available resources and preserve of fund. In this development, the primary goal is optimal preservation of assets for the future generations.

The environmental aspect of development is based on Holling theories, and pays close attention to stability of biolog-ical and physical systems. According to this theory, economic development must occur with respect to natural restrictions. Considering environmental impacts reduce disruption in cur-rent system and also guarantees future life on Earth.

Social aspect indicates developmental efforts for preserve of social structure. Social sustainability is obtained following by preserve of social health and decline of vulnerability against changes. From another point of view, rule of society
is considerable in acceleration and recognition of development process [6].

2) Sustainability Criteria: Different methods can be con-sidered for finding the sustainability indicators. One of the typical ways for finding the indicators is studying basic orientor satisfaction. In this method, system maintains three sub-systems including human system, support system, and natural system. The primary goal in this method is expansion of sustainability indicators in entire aspects of urban system that limits sustainable development in several minor indicators. Therefore, human system includes individual sub-system (so-cial and political systems), support sub-system (infrastructure and economical systems), and natural sub-system (resources and environment). Sustainability indicators in this method are illustrated in Table I. Notably, every item can include several measurement indicators based on rate of data access in every physical space [7].

Another way for finding sustainability indicator is track-ing goals. In this method, intended goals for sustainability approach is defined and indicators are selected with respect to them. Additionally, sustainability indicators must contain management tools for implementation and monitoring in urban
area. Further, indicatorsmustbe able to be measured tobe able to evaluate therateof sustainability in the next step. Sustainability indicators in this method are categorized according to Table II.

B. Vertical Development

1) Vertical Development Concept and Its Component: The contemporary thoughts about urban vertical development is formed in response to the urban sprawl, incline in energy per-formance, and optimal usage of non-renewable resources [8]. Before studying positive or negative consequence of vertical development, it is necessary to investigate reasons influencing formation of this kind of development in cities. Influencing reasons on formation of compact cities or sprawl cities are very close and relates. Table IV demonstrates reasons for urban development resulting the compact cities or sprawl cities [9].

Searching for sustainable urban form at late 1980 formed extensive academic arguments that led to introduction of ver-tical development. It refers to compact development or single central city with occupational and residential concentration in addition to other applications that shorten average distance from home to workplace or business center that minimize land use. In other word, in compact cities, emphasizes are on development of existence city centers and reclaimed lands and prevent of city spread in margin [10].

One of the features of compact cities is existence of public between pedestrian area and community facilities, so a public transportation service can respond to needs. Meanwhile, fun-damental development of buildings, streets, and public area attract people to city centers, and also serve to maximize the energy performance. People who likes compact cities believe this type of development promote social patterns. Furthermore, this can be considered as type of public-transit-oriented development [11].

Table Iv
Underlying Cause Of Urban Development

Cause of Urban Development :	Compact City	Sprawl City
Population growth		✓
Independence in decision making	7	✓
Economic growth	✓	✓
Industrialization	✓	✓
Speculation	7	✓
Tendency to keep lands	7	✓
Legal disputes	7	✓
Physical geography	7	✓
Development finance	7	✓
Cost of living	✓	✓
Lack of affordable housing	7	✓
Demands for more living space	✓	✓
General regulations of society	7	✓
Transportation	✓	✓
Wide streets	7	✓
Homes for single member family	7	✓
Core families	✓	✓
Stock and credit market	✓	✓
Development of governmental policy	✓	✓

2) Features of Compact City:

High density in residential and occupational area Incorporate applications
Proper classification for land use (Proximity of different applications in addition to small size of lands)
Increase of social and economical interaction Continuous development
Urban development with lawful restriction
Importance of urban infrastructure particularly water and wastewater
Multimodal transport
High accessibility at local and regional areas
High communication between passages and their internal or external interconnection through pedestrian zones and bike lanes
Low outdoor space
Integrated control for land development plan
Efficient governmental funds for providing facilities and municipal infrastructure [11]

3) Result and Consequence of Compact City:
Negative Consequence:
High building density
Decline in use of light and air for residents Incline in land prices
Positive consequence:
Better access to facilities
Incline in economical attractiveness Non-horizontal proliferation
Preserving lands with agriculture and ecological val-ues [12]

C. Vertical Sustainable Development

New urbanism, transit-oriented development, and smart growth are the primary modern standpoints in sustainable

Table I
Sustainability Criteria In Basic Orientor Satisfaction Approach

Direction	Subsystem	Sustainability Criterion
Existence	—	The per capita income of residents in comparison with a per capita income of urban
	—	Net growth revenue from providing infrastructure
	—	Destruction of forests and agriculture lands
Effectiveness	Human	Share of vulnerable population affecting by social problems
	Support	The salary level in comparison with personal income of residents
	Natural	Renewable energy sources
Freedom of action	Human	Unemployment rate in active population
	Support	Energy efficiency
	Natural	Share of natural sources under sustainable management
Safety	Human	Share of harm and disease in society
	Support	Share of foreign trade in comparison with overall trade in city area
	Natural	Dependency ratio on non-renewable resources
Compatibility	Human	Literacy rate of vulnerable groups
	Support	Entrepreneurial ratio of university graduates
	Natural	Biological diversity indicators
Symbiosis	Human	Share of people with special ability or position in comparison to the entire population
	Support	Environmental footprint of industrial activities and services
	Natural	Rate of change in biological diversity
Psychological needs	Human	Income ratio between rich and poor people
	Support	Number of people covered by public services
	Natural	Recreational area ratio in the city

development that provide similar ideas and policies in compact cities. They are briefly introduced in below.

1) New Urbanism: It's a new movement that provides suggestions for low-density suburban living patterns in the United States. Its fundamental principles include compactness, walkability neighborhoods with specific ranges, defining a specific center with public space, public transportation stations, public buildings and business centers, interconnected street network, combining different applications and providing different types of houses.

2) Public Transit-Oriented Development: This movement targets one of the primary suggestion of new urbanism. It includes societies with different applications having 609.6 meter average pedestrian distance from public transportation stations and areas with business centers. The fundamental principles for this approach includes combination of residential, commercial, administrative and outdoor applications,considering public transportation, walkability, and cycling. In Equation (1), H is Shannon entropy, Pi is ratio of built area of zone i over entire built area, and n is number of zones. The value of Shannon entropy varies between zero and Ln(n). Zero entropy implies physical development is very dense; while Ln(n) implies physical development is sprawl. In fact, when entropy goes beyond the Ln(n), ugly urban development happens.

2) Holdren Model: One the methods being used for de-termining ugly urban development is Holdren approach. This approach determines how much of urban development is due to population growth and how much of it is due to ugly urban development. According to this model:

$$\text{Ln}\left(\frac{\text{city areaat end of period}}{\text{city area atbeginningof period}}\right) =$$

$$\text{Ln}\left(\frac{\text{populationat end of period}}{\text{population atbeginning of period}}\right) +$$

3) Smart Growth: This movement is emerged against tra-

$$\text{Ln}\ \frac{\text{gross per capita at end of period}}{}$$

ditional approaches of planning and making policy. It conveys providing capacity for urban growth in a smart way that is transparent in economical aspect, respond properly to environmental requirements, and being clarified through a collaborative approach. The fundamental principles for this approach are: promoting combination of different applications, developing walkability and public transportation, promoting urban investment, using national and local resources for im-proving infrastructures [12].

D. Analytical Models for Physical Urban Development

1) Shannon Entropy Model: It is being used for analyzing and explaining the ugly growth of a city. The general structure of this model is:

$$H = \sum_{i=1}^{n} P_i \quad Ln(P_i) \qquad (1)$$

gross per capita at beginning of period (2)

III. Methodology

The target in this study is in form of practical, and the followed approach is in form of causal and correlation. The theoretical framework in this study is based on library method, literature review, and study of international experiences. For Tehran case, the development type is determined based on available statistics using analytical models for physical urban development. Eventually, sustainability indicators are fitted based on available statistics for the Tehran case, and for every indicator, a colored map is exported illustrating the most to least match of physical context with indicator of interest using the GIS software.

Table II
Sustainability Criteria In Tracking Goal Approach

Indicator	Target	Goal
Percentage of population in extreme multi-dimensional poverty	End extreme poverty, including absolute income poverty	End Extreme Poverty including Hunger
GNI per capita	Each country reaches at least the next income level and promotes decent work	Promote Economic Growth And Decent Jobs within Planetary Boundaries
Percentage of children receiving at least one year of a quality pre-primary education program	All children under the age of 5 have access to quality early childhood development programs and policies	Ensure Effective Learning for All Children and Youth for Life and Livelihood
Average number of hours spent on paid and unpaid work combined (total work burden), by sex	access to justice, and participation in political and economic life on the basis of gender, ethnicity, religion, disability, national origin, and social or other status	Achieve Gender Equality, Social Inclusion, and Human Rights
Percentage of population without effective financial protection for health care	Ensure universal coverage of quality healthcare	Achieve Health and Wellbeing at all Ages
Crop water productivity (tons of harvested product per unit irrigation water)	Ensure sustainable food production systems with high yields and high efficiency of water, soil nutrients, and energy	Improve Agriculture Systems and Raise Rural Prosperity
Percentage of urban population with incomes below national extreme poverty line	End extreme urban poverty, expand employment and productivity, and raise living standards	Empower Inclusive, Productive and Resilient Cities
Share of the population with access to modern cooking solutions, by urban and rural (%)	Decarbonize the energy system, ensure clean energy for all, and improve energy efficiency, with targets for 2020, 2030 and 2050	Curb human-induced climate change and ensure sustainable energy
Protected areas overlay with biodiversity	Secure ecosystem services by adopting policies and legislation that address drivers of ecosystem degradation	Secure Biodiversity, and Ensure Good Management of Water, Oceans, Forests and Natural Resources
Share of companies valued at more than ($1 billion) that publish integrated reporting	Governments (national and local) and major companies support the SDGs, provide integrated reporting by 2020	Transform Governance and Technologies for Sustainable Development

IV. CASE: TEHRAN METROPOLIS

A. Case Introduction

Tehran is the first metropolis in Iran. It is the capital and includes 22 zones. Because of its crucial role in politics, economy, culture and so on and also its population growth, it undergoes an extreme physical change. According to statistics gained in 2011, this city is the biggest city in the west Asia with 8244759 inhabitants and 750 square kilometer area.

This city confronts with different kind of problems, and efforts are being taken to cope with them. Nowadays, physical and population growth for this city is among the notable subjects and it is being tried to control and draw a plan for this issue. In this section, physical growth of Tehran city are analyzed using Shannon entropy model and Holdren model between 1996 and 2006 to determine the dominant developmental approach (compact or sprawl) for the case.

B. Studying Urban Developmental Models in Tehran Metropo-lis

Therefore: $\mathrm{Ln}(1{:}1216) = \mathrm{Ln}(1{:}2109) + \mathrm{Ln}(1{:}3581)$ (4)

By dividing the both side of Equation (4) by Ln(1.3581) will have:

$1 = 0{:}37 + 0{:}63$ (5)

Therefore, from 1996 until 2006, 37 percent of physical growth in Tehran was due to population growth and only 63 percent was related to horizontal growth and sprawl devel-opment. This issue resulted in decrease of gross population density and increase of gross per capita of municipal land.

2) Shannon Entropy Model: According to Table V and Table VI, the entropy is 2.0087 in 1996. The maximum value for the entropy is 3.091. Being close to the maximum value implies that sprawl physical development of Tehran case. The entropy is 2.3329 in 2006 which implies sprawl physical development for Tehran case is increased from 1996 to 2006. Figure 2 demonstrates a comparison between entropy in 2006 and 1996.

1) Holdren Model: According to Heldron model:

1) Holdren Model: According to Heldron model:

$$Ln\left(\frac{\text{city area at } 2006}{\text{city area at } 1996}\right) = Ln\left(\frac{\text{population at } 2006}{\text{population at } 1996}\right) + Ln\left(\frac{\text{gross per capita at } 2006}{\text{gross per capita at } 1996}\right)$$

C. Feasibility of Sustainable Vertical Development in Tehran

As illustrated in the previous section, urban development oc-curred in form of horizontally for the Tehran case. In addition, based on studies in theoretical principles, vertical development merely cannot respond to sustainability requirement in every

(3) location. Therefore, vertical development must be considered based on sustainability indicators, so only parts of the city

TABLE V
SHANNON ENTROPY CALCULATION FOR TEHRAN IN 2006

Zones	Area (hectare)	P_i	$Ln(P_i)$	$P_i\ Ln(P_i)$
1	6400	0.03034	-3.4954	-0.106
2	3200	0.01517	-4.1864	-0.0635
3	4287	0.02032	-3.8971	-0.0792
4	95000	0.45032	-0.7978	-0.3593
5	5287	0.02506	-3.6848	-0.0923
6	2138	0.01013	-4.5952	-0.0466
7	1536	0.00728	-4.9198	-0.0358
8	1339	0.00635	-5.0672	-0.0322
9	1960	0.00929	-4.6777	-0.0435
10	807	0.00383	-5.5727	-0.0213
11	1260	0.00597	-5.1159	-0.0306
12	916	0.00434	-5.4491	-0.0237
13	1283	0.00608	-5.0994	-0.031
14	5414	0.02566	-3.6612	-0.094
15	3475	0.01647	-4.1043	-0.0676
16	1651	0.00783	-4.8536	-0.038
17	822	0.0039	-5.5467	-0.0216
18	3809	0.01806	-4.0118	-0.0724
19	8919	0.04228	-3.1629	-0.1337
20	2300	0.0109	-4.5189	-0.0493
21	5156	0.02444	-3.7131	-0.0908
22	54000	0.25597	-1.3625	-0.3488
...	210959	1	-91.4935	-1.8812
H		2.3329		

TABLE VI
SHANNON ENTROPY CALCULATION FOR TEHRAN IN 1996

Zones	Area (hectare)	P_i	$Ln(P_i)$	$P_i \; Ln(P_i)$
1	5928	0.038163	-3.2649	-0.1246
2	2765	0.0178	-4.0285	-0.0717
3	2232	0.014369	-4.2405	-0.0609
4	17919	0.115359	-4.4619	-0.5147
5	4485	0.028873	-3.5439	-0.1023
6	1655	0.010655	-4.5375	-0.0483
7	1745	0.011234	-4.4918	-0.0505
8	1674	0.010777	-4.5282	-0.0488
9	1916	0.012335	-4.3981	-0.0542
10	603	0.003882	-5.5467	-0.0215
11	1409	0.009071	-4.699	-0.0426
12	1416	0.009116	-4.699	-0.0428
13	863	0.005556	-5.1849	-0.0288
14	1087	0.006998	-4.9618	-0.0347
15	2668	0.017176	-4.0628	-0.0698
16	1565	0.010075	-4.5952	-0.0463
17	879	0.005659	-5.1672	-0.0292
18	3422	0.02203	-3.8167	-0.0841
19	1953	0.012573	-4.374	-0.055
20	1723	0.011092	-4.5008	-0.0499
21	5440	0.035022	-3.3524	-0.1174
22	91986	0.592186	-0.5239	-0.3102
total	155333	1	-92.9797	-2.0083
H		2.0083		

could have the potential for vertical development. For this reason, it is necessary to determine vertical sustainability indicators based on previous studies and evaluate them for the Tehran case. Following this approach further, with respect to sustainability indicators initially evaluation criteria are selected with their allowable zones for vertical development for Tehran case. These criteria in overall are categorized in econom-ical, social, environmental, physical, safety and infrastruc-ture. Afterward, indicators are selected with respect to them considering available information resources and restriction imposed by choosing them. After converting information of every indicators in form of raster data for the entire Tehran

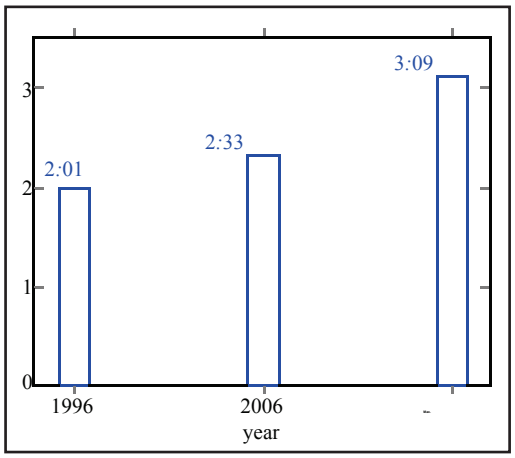

Fig. 2. Entropy variation in the last decade

area, map layer is created using space analytical approach in GIS environment. Table IX illustrates feasibility of sustainable vertical development for Tehran case.

Finally, for extracting desirability for every locations for building a tall building in the city area, weighted overlay technique is used. This technique required weight extraction for every indicators based on a same scale for every indicators. For this purpose, weight of every indicator is determined through gathering expert opinion for design, questionnaire and data process of gained information. Then, overlay technique is performed for the obtained maps based on the extracted weights, and eventual prioritization of every zones is provided based on the selected evaluation indicators. Figure 3 shows zones with higher priority for vertical sustainable development.

V. CONCLUSION

Sustainable development is introduced in the recent urban planning literature. It is one of the subject in close relation with urban planning. It is studying the urban shape in accordance

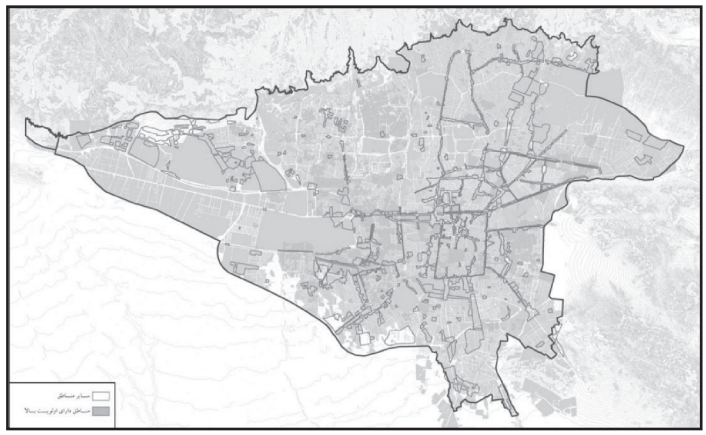

Fig. 3. Zone with high priority for sustainable vertical development

with the sustainability principles. Discussions around this subject are being studied in a range between centralization and decentralization, which are respectively defined as compact city and sprawl city. In late twenty century, due to environ-mental, social and economical consequent of urban sprawl, noticeable criticism was raised in the world. In response to this issue in urban planning literature, compact city is introduced, in which advantages like decreasing car travel, protecting local and valuable lands, promoting social equality, restoring deteriorated urban areas, and obtaining long-term development were presumed. Table VII illustrates vertical and horizontal development with respect to sustainability criteria.

According to aforementioned points and illustrated compar-ison, it is reasonable that compact city is in better match with sustainability development criteria. Nevertheless, it cannot be concluded that increase of compactness implies increase of sustainability and compact city is the unique solution for sus-tainable urban development. Therefore, for gaining sustainable urban development, optimal solution must be concluded by considering the city in its time and balancing the positive and negative consequences for every urban forms. Meanwhile, through measurement of physical urban development for the Tehran case using the aforementioned models, it is illustrated that sprawl pattern is dominantly influencing the growth and development of the city. According to this point, feasibility of vertical sustainable urban development is studied, and based on five categorized sustainability indicators, only parts of the urban area are prioritized for the vertical development.

Table Vii
Comparative Study Between Compact City And Sprawl City Approaches

Indicator	Compact city	Sprawl city
Vegetation and green space	Preserving valuable agriculture lands	Indiscriminate use of green space
Energy consumption	Decrease in fossil fuel consumption	Indiscriminate use of fossil fuel
Using car	Reducing traveling with car	Car dependency and ease of use
Air and water pollution and environmental consequences	Decline in use of light and air because of compactness	Increase of pollutant because of using fossil fuel
Social interaction	Increase of social conflicts	Increase of social apartheid
Crime rate	Increase in crime in compact area	Decrease in crime
Functional outdoor space	Providing open and public space	Lack of functional outdoor space
Street network and accessibility	Continuous road network, walkability, and cycling lane network	Discontinuous roads and increase of road area
Housing satisfaction	dissatisfied with life quality	Incline in housing and life quality satisfaction
Population density	High population density	Low population density
Equality in facility distribution	Better access to facilities because of their concentration	Scattered facility distribution
Public transportation	Advanced public transport system	Inefficient public transport
Land application	Land with combined applications	Zoning functionality of land application

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