Original Article

Maintaining health and sustainability of urban metabolism ecosystem in line with sustainable development: a case study of Qarchak, Iran

Farzad Delivandani [1], Azita Rajabi [1 *], Ali Nouri Kermani [1]

[1] Department of Geography and Urban Planning, Central Tehran Branch, Islamic Azad University, Tehran, Iran.
***Corresponding author and reprints: Azita Rajabi**, Associate Professor, Department of Geography and Urban Planning, Central Tehran Branch, Islamic Azad University, Tehran, Iran.
Email: azitarajabi@yahoo.com
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Abstract

Background: The present study aimed to evaluate the urban metabolism in line with sustainable development of Qarchak city, Iran.

Methods: The present study was applied in terms of type and descriptive-analytical in terms of method**.** The statistical population of the study included Qarchak city as one of the cities of Tehran province with a population of 231075 people based on 2016 census. It is located in the northwest of Varamin city. Information was collected through library studies, documents and databases were checked. After identifying the criteria, they were converted into quantitative indices and the indices were weighted and prioritized within the framework of AHP weight model. Data analysis was done with the Metabolic Outcomes Assessment (MIA) method.

Results: The final score of the study area was 29.61, while the optimal status is 60.64. Therefore, the current status of the area compared to the optimal status, gained about 45% of the scores. It indicates that the metabolic status of the study area is poor. Also, according to experts, water criterion with a weight of 0.388 has the highest rank and air criterion with a weight of 0.075 has the lowest rank and importance. Also, the incompatibility coefficient is 0.09, which is acceptable.

Conclusion: Based on the results of the present study, understanding the deep relationship between the city and the environment to solve urban and environmental problems, optimization of systems and multiple natural and human processes is essential that should be considered by public people and urban planners.

Keywords: Ecosystem; Health; Iran; Urban Metabolism.

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Introduction

The city is like a living and evolving creature that evolves over time, and in many cases, the city has biological characteristics of a living creature. These characteristics include organism, metabolism, tissue and skeleton (1). Urban metabolism refers to socio-ecological exchange processes and developments in cities. This concept, rooted in the nineteenth century and biology discipline, has emerged in recent decades as an important topic in assessing, measuring, explaining, and addressing the nature of urban environmental change (2). One of the concepts of sustainable development is urban metabolism, which refers to the exchange processes by which cities release raw materials, energy and water into environment and convert them to human biomass and waste. Urban

metabolism has raised many criticisms of specific social and economic arrangements, in which some forms of flow within the city are prioritized and / or marginalized (3). The close relationship between urban metabolism and urban sustainability emphasizes the need to study all urban processes with an integrated approach to solve the difficult challenge of material, energy, water and food flows in cities (4). Urban metabolism is a concept that does not have a good status in Iran. Uncontrolled population growth and urbanization of Qarchak city has increased resource consumption and pollution. Also, the linear pattern of resource consumption in the city is a low-interest sequence.

Environmental studies indicate that one of the major environmental problems in Qarchak city is the existence of polluting and disturbing occupations such as tanning workshops, melting metals (lead) of brick factories, directing sewage to unsuitable environment, recycling workshops, air pollution, lack of network for collection and treatment of municipal wastewater, active mines, industrial pollution resulting from consumption of fuel products (oil pollution) as well as industrial wastes containing zinc oxides and aluminum due to the activity of iron and aluminum casting units and the production of slag by them, etc., which have negative impacts on the health of citizens. Qarchak city has a high volume of waste and sewage production. Also, the population of this city is growing and this issue causes the maximum utilization of the environmental capacities of the city, and considering the importance of the impact of environmental issues on the city's resources, therefore, the current research was conducted with the aim of explaining the pattern of healthy urban metabolism in the development cycle of Qarchak city.

Methods

The present study was considered as applied research in terms of aim, descriptive-analytical in terms of method and survey in terms of the required data collection method. Also, a questionnaire was used to collect data among urban experts. The main research tools were observation and a questionnaire. To explain the research problem, the approach of experimental research and sustainable urban development was used. Also, this study was one of the applied studies in terms of aim and its results can be used to solve economic, social and environmental problems in Qarchak city. Its statistical population included city managers and specialists who were involved in the area of city and urban planning. In the next step, the process of converting the criteria into quantitative indices was performed and the indices were weighted and prioritized within the framework of Analytical Hierarchy process (AHP) weight model using Expert Choice software.

Metabolic Impact Assessment (MIA) method was used to analyze the information and achieve the research results. Accordingly, the data required for analysis and assessment were formed based on the indices obtained from the study of theoretical foundations related to the area of urban metabolism and urban patterns and also based on the case study of Qarchak city in relation to these data. Accordingly, the metabolic analysis of this city in relation to urban patterns to assess the sustainability and urban management was performed.

In the first part of Baroosh, information was collected based on the MIA method (information available in the municipality and related bodies) and the second stage was based on the AHP method using a researcher-made questionnaire that experts answered. The questionnaire for the investigation of the metabolism of Qarchak city was done in two parts. Composed. The first part includes the personal questions of the audience, and the second part is related to the questions of measuring metabolism in the urban area. In this research, according to the conditions of the research, content validity, especially its formal type,

has been used. Thus, after setting up the questionnaire and designing the necessary items for the research variables, it was shown to the professors and specialists in urban affairs. After examining and matching the items with the measured variables and the conditions of the research environment, they expressed their opinions, and the researcher, after applying his opinion on them and according to the situation of Qarchak city, proceeded to finalize the questionnaire. In this research, the AHP questionnaire (pairwise comparisons) is used, considering that these comparisons are not a statistical questionnaire, but only a mathematical matrix where the variables are compared two by two, so the variable is not measured by metrics that we want to measure the correctness of this measure. Let's check, that pairwise comparisons are just a mathematical matrix and do not have the meaning of a statistical questionnaire. Therefore, since it is not a questionnaire, the validity and reliability of the pairwise comparison matrix have no meaning.

To measure the reasonableness of paired comparisons, only the inconsistency rate is used, if the inconsistency rate is less than 0.1, it means that the comparisons are logical and correct. The calculation result of inconsistency rate estimation shows that the value of the rate is less than (0.1) and is at an acceptable level. In this stage, three steps were used, which consist of selecting the expressions of the urban metabolism measurement tool based on the results of the indicators used by other researchers in this field. In the next stage, the validity of the questionnaire is examined. In the present study, two methods were used to determine the validity of the instrument: face validity and content validity

Content Validity: In the current research, the face validity, content validity and construct validity of the questionnaire have been examined, so that the questions of each index are analysed according to the urban metabolism and the development cycle. The opinions of 15 experts in the field of urban planning were used to determine the content validity of the tool. to express their opinions about the content, clarity, simplicity and arrangement of expressions of the urban metabolism measurement tool.

Face validity: In this research, in order to determine the face validity of the urban metabolism measurement tool, the researcher tried to use the writing style, phrasing and logical and exciting appearance for the tool. Also, the percentage of clarity and simplicity of expressions and opinions of experts was used in the content validity determination stage in the tool judgment stage to improve the face validity of the tool. And finally, the questionnaire was adjusted with several stages of revision and modification and will be distributed and completed among the sample members by referring to the experts.

Results

Description of demographic characteristics of the subjects

Based on the Table 1, in terms of gender frequency, males with 8 people (53%) had a higher frequency than females. In terms of education level, the highest frequency belonged to people with bachelor with 7 people (47%). In terms of age, people in the age group of 30 to 39 years with 6 people (40%) have the highest percentage of the

Table 1. Distribution of demographic characteristics of the subjects

Variable	Subgroups	No.	%
Gender	Female	7	47%
	Male	8	53%
Level of Education	Associate Degree	3	20%
	Bachelor	7	47%
	Master	5	33%
Age (years)	Less than 30	2	13%
	30 - 39	6	40%
	40 - 49	4	27%
	50 and older	3	20%
marital status	Married	6	40%
	Single	9	60%

sample. In terms of marriage, the single group with 9 people (60%) had a higher frequency.

Land cover criteria

According to the normalization of land cover criteria, source: author is showed that about index consisted of total built area (current status: 0.10, optimal status:1, current status normalized index: 22.5), area of reconstructed areas (current status: 0.15, optimal status: 1, current status normalized index: 35.1), per capita green space (current status: 0.19, optimal status: 1, current status normalized index: 42.4) in total is (current status: 0.44, optimal status: 3, current status normalized index: 100), mean (current status: 0.14, optimal status: 1).

The per capita green space index has the best performance. The indices of the total built area (0.44)and the area of the reconstructed areas are in a poor status compared to the optimal status(3). The mean performance of land cover criteria is 0.14% of unfavorable status. Figure 1 shows the performance figure of the indices compared to their means.

$$d_j = \frac{x_j}{\sum_{j=1}^{n} x_j} \times 100 \quad (1)$$

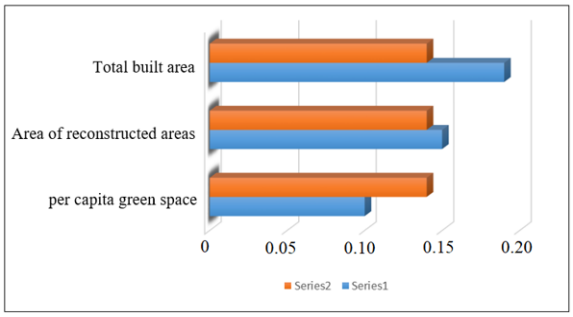

Figure 1. Performance of land cover indices compared to mean

Seri1: current situation
Seri2: Ideal suitation

Water criterion

Based on Table 2, the per capita water consumption index has the best performance and the population connected to the domestic sewage network has the worst performance. As mentioned before, the water criterion is the most important element of urban metabolism. Based on the obtained information, it can be stated that per capita water consumption and wastewater production are not far from the optimal level, but the level of water consumption by the residential sector is relatively high and the rate of reuse of water consumption is a crucial factor in proper metabolic performance of the study area. Due to severe shortage of sewage collection network cover, the performance mean of the water percentage criterion is in good status. Therefore, the overall performance of this criterion is more favorable than other criteria (Figure 2).

Table 2. Normalization of water criteria indices, source: Author

Criterion	Index	Current status	Optimal status	Current status normalized index
Water	Per capita water consumption	0.98	1	27.01
	Per capita water consumption by the residential sector	0.70	1	20.89
	Share of water consumption by the residential sector	0.62	1	17.88
	Per capita production of wastewater	0.80	1	25.21
	Population connected to the domestic sewage network	0.10	1	9.01
	Total	3.20	5	100
	Average	0.64	1	**********

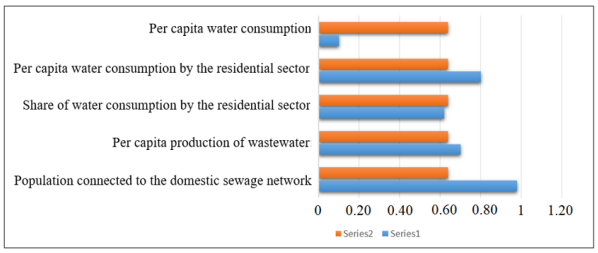

Figure 2. Performance of land cover criteria compared to mean

Seri1: current situation
Seri2: Ideal situation

Material criterion

Based on Table 3, the per capita solid waste collected per year has the best performance and the worst performance is related to the per capita construction waste. Also, other indices of this criterion are in poor status compared to the optimal status in Figure 3.

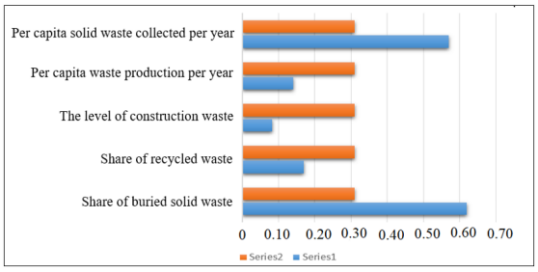

Figure 3. Performance of material criterion indices compared to mean

Seri1: current situation
Seri2: Ideal suitation

Air quality criterion

Based on normalization of air quality criterion indices, The results of this research, the criterion about air quality is showed that index consisted of suspended particles less than 10 microns (current status: 0.17, optimal status: 1, current status normalized index: 12.80), suspended particles less than 2.5 microns (current status: 0.28, optimal status: 1, current status normalized index: 19.45), sulfur dioxide (current status: 0.54, optimal status: 1, current status normalized index: 37.35), nitrogen dioxide (current status: 0.42, optimal status: 1, current status normalized index: 30.40), total (current status: 1.41, optimal status: 4, current status normalized index: 100) and with mean (current status: 0.35, optimal status: 1). The carbon dioxide pollutant index has the best performance and the worst performance is related to the index of suspended particles of less than 10 microns. Also, the index of suspended particles less than 2.5 microns is in a poor status compared to other indices. The mean performance of air quality criterion is 35% of the optimal status. This rate indicates the inappropriate status of the indices of this criterion in the study area compared to optimal status. Air pollutants seem to have many negative impacts on the metabolic performance of the area. Figure 4 shows the performance of the indices compared to their means.

Table 3. Normalization of material criterion indices, source: Author

Criterion	Index	Current status	Optimal status	Current status normalized index
materials	Per capita solid waste collected per year	0.62	1	35.64
	Per capita waste production per year	0.17	1	15.42
	The level of construction waste	0.082	1	5.66
	Share of recycled waste	0.14	1	10.94
	Share of buried solid waste	0.57	1	32.34
	Total	1.528	5	100
	Mean	0.31	1	**********

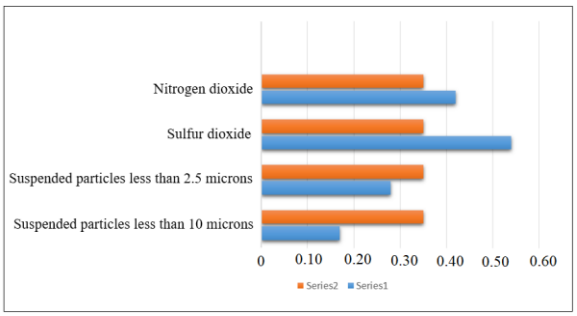

Figure 4. Performance of air quality criterion indices compared to mean

Seri1: current situation
Seri2: Ideal suitation

Transportation sector energy criterion

Based on Table 4, public transportation use index has the best performance, and the worst performance is related to the percentage of renewable energy use, relative to total energy consumption. This theorem shows that the share of renewable energy use is not at a good level. The mean performance of energy criterion is 0.41% of the optimal status in Figure 5.

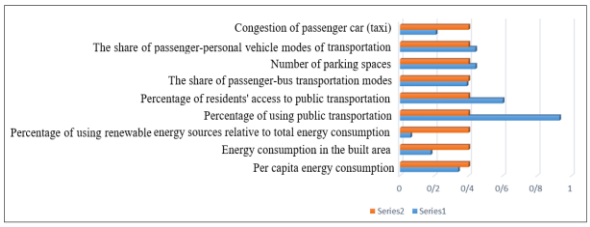

Figure 5. Performance of energy criterion indices compared to mean

Step 3: Weighing the criteria and analyzing and evaluating the metabolic of the area based on the criteria

In this step, based on the values obtained from the sum of the indices of each criterion, criteria were evaluated and finally all the criteria of the current status and the optimal status were evaluated to determine the overall metabolic status of the study area in comparison with its optimal status. In order to more accurately assess the current status of the urban metabolism, the coefficient of importance (weight) was determined for each criterion. The importance of criteria is determined based on the studies of theoretical foundations.

To weigh the criteria, we compared them in pairs. The basis for comparison in this regard was the comparison of the Saati 7-quality table. For equal importance, a score of 1, for a little more importance, a score of 3, for more importance, a score of 5, and for much more importance, a score of 7, and for absolute importance, a score of 9 was considered. Also, scores of 6, 4, 2, and 8 were compared for intermediate values. Pairwise comparison was done in a 5 * 5 matrix. To calculate the coefficient of importance of the criteria, we first obtained the geometric mean of the rows of the matrix and then normalized them (Table 5).

Table 4. Normalization of energy criterion indices

Criterion	Index	Current status	Optimal status	Current status normalized index
Energy	Per capita energy consumption	0.34	1	9.76
	Energy consumption in the built area	0.18	1	8.79
	Percentage of using renewable energy sources relative to total energy consumption	0.062	1	1.23
	Percentage of using public transportation	0.93	1	18.55
	Percentage of residents' access to public transportation	0.60	1	5.42
	The share of passenger-bus transportation modes	0.39	1	14.52
	Number of parking spaces	0.44	1	16.32
	The share of passenger-personal vehicle modes of transportation	0.44	1	16.32
	Congestion of passenger car (taxi)	0.21	1	9.09
	Total	3.592	9	100
	Mean	0.40	1	********

Table 5. Matrix of pairwise comparison of criteria and determination of their coefficient of importance

Criterion	Land cover	water	materials	Air quality	energy	coefficient of importance	Normalized coefficient
Land cover	1	4	1	4	2	2.1	0.1924
Water	4	1	5	3	4	2.92	0.2711
Materials	1	5	1	1.20	1.40	1.53	0.1223
Air quality	4	3	1.20	1	3	2.12	0.2220
2Energy	2	4	1.40	3	1	2.01	0.1922

After determining the coefficient of importance of the criteria, the sum of the values obtained from the indices of each criterion obtained in the previous step was considered as the value of each criterion and these values were normalized to its optimal status in each criterion. Table 6 shows the sum scores of criteria, metabolic status of Qarchak city.

Based on the calculations performed and the results obtained from the assessment criteria, it can be said that the final score of the study area in the current status is 29.61, while the final score of the optimal status is 60.64. In other words, the current status in the area has gained about 45% of the scores compared to the optimal status. It indicates that the metabolic status of the study area based on the information obtained is poor.
In this step, the relevant experts in the municipality were asked to weigh the criteria affecting urban management in Qarchak city to measure sustainable urban metabolism according to a 9-quantity questionnaire. Then, the questionnaires entered into Expert Choice software.

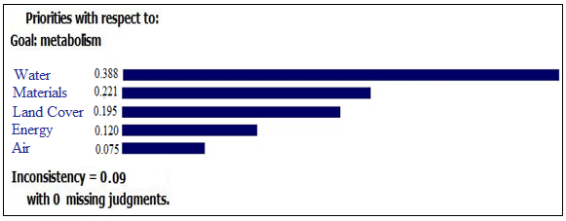

Figure 6. Ranking of criteria affecting urban management in Qarchak city to measure sustainable urban metabolism

According to Figure 6, water criterion with a weight of 0.388 has the highest rank and air criterion with a weight of 0.075 has the lowest rank and importance. Also, the incompatibility coefficient is 0.09, which is acceptable.

Discussion

According to the present study, to analyze and evaluate the urban metabolism of Qarchak city, after reviewing the theoretical foundations and research literature as well as survey and documentary studies and assessing the opinions of experts in the study area, the criteria for this purpose in Qarchak city were identified and examined. These

Table 6. Metabolic assessment of the area based on criteria

Criterion	Criterion value		Criterion weight	Normalized criterion		Final score of criterions	
	Current status	Optimal status		Current status	Optimal status	Current status	Optimal status
Land cover	0.44	3	0.1924	15.18	41.42	2.92	7.96
Water	3.2	5	0.2711	40.5	59.25	10.97	16.06
Materials	1.581	۵	0.1223	22.34	70.34	2.73	8.60
Air quality	1.41	4	0.2220	19.26	72.23	4.27	16.03
Energy	3.592	9	0.1922	45.4	62.41	8.72	11.99
sum	10.23	26	1	139.68	306.15	29.61	60.64
Overall performance	****	****	****	****	****	45.125	100

criteria were water pollution, soil pollution, noise pollution, industrial pollution, waste pollution and air pollution. Since each of these dimensions and criteria have different degrees of importance in achieving the share of each of these criteria in the metabolism of Qarchak city, the multi-criteria decision method (hierarchical analysis) was used to analyze each of them based on the importance, impact and role they play in the instability of the city. Based on the calculations performed and the results obtained from the assessment criteria, it can be stated that the final score of the study area in the current status is 29.61, while the final score of the optimal status is 60.64. In other words, the current status of the study area compared to the optimal status has achieved about 45% of the score, and indicates that the metabolic performance of the study area based on the obtained information is poor. Also, based on the experts, water with a weight of 0.388 has the highest rank and air with a weight of 0.075 has the lowest rank and importance. Also, the incompatibility coefficient is 0.09, which is acceptable.

In general, the results of the study indicate that the Qarchak city according to the criteria examined in urban metabolism is in an unstable environmental status and among the criteria in urban metabolism, the most important factor is the water and pollution index with a weight of 0.388. Based on the results of the present study and based on the results of the study conducted by Wellman, investigating water, food and fuel consumption along with wastewater production, waste and air pollution to determine inflation and per capita inflow and outflow for a city to sustain city dwellers in their residence place, workplace and recreation place is necessary (5). Considering the importance of examining the urban metabolism, it can be stated that urban metabolism is considered as a basis in sustainable urban design and urban policies. Urban policy needs to be studied at different scales including global scale, regional, national, urban and even at the domestic level (6). In other words, urban metabolism considers the city as a alive creature g and a broad framework to analyze the relationship of input and output sources to the urban system and its relationship with the environment (7), since climate, materials, land and natural resources (forests, plant species, etc.) are the most important of these biological needs of cities that they need for their development and survival (8). Nowadays, providing safe air and even safe water in cities is one of the most important urban issues, and it requires heavy costs. In general, water pollution is adverse and unfavorable changes with physical, physiological and chemical properties that threaten human life and other living organisms (9). Uncontrolled and uncoordinated variety of colors, forms, light and kind and the accumulation of heterogeneous, unbeautiful, unattractive and man-made visual elements in the urban space, which is a matter of aesthetics and its adverse impacts reduce a person's ability to enjoy or observe the landscapes and disrupt its observation is called visual pollution (10). Accumulation of various wastes in different parts of the city is one of the familiar landscapes of cities (11).

Existence of a coherent network with formal, functional and semantic unity ensures the quality of city spaces and better understanding of them. Cohesion is an important principle in the structure of green networks, since both it affects the sustainability of green spaces structurally and functionally. It is also effective in sustainability and spatial cohesion of cities, improving the climatic conditions, creating active natural ecosystems in urban environments, improving the quality of urban life and increasing the livability of cities (12). Functionally, green infrastructure is one of the most efficient ways to solve the climatic and environmental problems caused by limited vegetation in densely populated cities with high construction density (13). Since roadside pollution has been caused by other

elements in recent years, heavy metals are in direct contact with humans and animals through the inhalation of soil dust, or they may enter the food chain. For example, they might be absorbed into body through eating vegetables. Several studies indicate that there is a strong association between the level of lead diesel or lead emitted or added to diesel and its level in different environments such as air, soil, snow, water (14). Urban extraction and urban resilience to stresses caused by the water crisis and the consequences of cities' dependence on each other for water resources increase each other (15). It can be argued that understanding the processes of urban metabolism allows for more sustainable development and management of cities by optimizing the use of available resources and increasing environmental protection (16). At a more practical level, infrastructure, open and green spaces, roads and different types of infrastructure are considered to achieve the goals of sustainable development, such as walkability, livability, conservation of natural resources and safety (17). The creation of a healthy city requires the existence of parameters at micro levels in cities, which are referred to as indices of quality of life (18). Healthy societies have unique characteristics but common principles, which allow us to consider them as a whole. The 14 principles of a healthy city are sustainable living, safety and security, economic productivity, cooperation, accessibility, balance, adaptability, dynamism (regular development), identity, beauty, diversity, leisure productivity, and sense of belonging (19).

Sustainability of cities is a local embodiment of its principles on a global scale and includes perspectives on the use of city-dependent resources and other ongoing challenges of socio-economic conditions. Cities can be important laboratories in assessing and reducing human impacts on the natural ecosystem (20). With accounting for about three quarters of all environmental pollution and with the destruction of nature, the pollution of the urban environment has had many negative impacts on human life and even the structure of cities (21).

Recommendations

Finally, we can refer the general measures that can be taken to improve the metabolism of Qarchak city. These measures include optimizing energy consumption, maximizing energy efficiency, maximizing the share of renewable energy sources, using clean energy in public transportation, developing green spaces and paying attention to their extent and distribution in the area, reconstruction of worn tissues, non-destruction of buildings until the actual wear, change of industrial land uses to green uses and mixed residential-commercial areas, minimizing water consumption, minimizing damage to the natural water cycle, optimizing water recycling and reuse, minimizing waste production, optimizing material recycling, proper use of recycled materials for material consumption and energy production, and minimizing waste disposal.

Conclusion

In healthy and sustainable cities, not only too much pressure from the biosphere on residents and citizens, but also the behavior of citizens is such that the ecological capacity is significantly increased. In this regard, city managers can control the ecological capacity of cities by controlling the level of environmental pollution in the city and the optimal use of urban ecological assets. Accordingly, several methods have been developed to assess environmental impacts and calculate the sustainability of urban areas, but they have been used one-dimensionally or in specific contexts. In this regard, urban metabolism as a tool to assess the ecological impact and potential of the urban environment is a new method that can clarify that increasing consumerism is directing the cities towards

increasing instability and ecological incapacity. In the last two decades, due to increasing number of immigrants, Qarchak city has experienced high physical growth, and this uneven growth and population density and special geographical location has caused environmental challenges in this city. The environmental issues of Qarchak city, caused by internal and external factors, widely affect health, mental health, economic, social, and urban environmental health. If they are not controlled in a strategic urban development plan, its consequences and impacts will remain not only for the present generation but also for future generations. As mentioned earlier in theoretical foundations studies, the urban metabolism cycle has inputs and outputs whose interactions occur in the urban system, which here is limited to urban structures, models, and forms. To achieve greater sustainability, it is necessary that linear metabolism, which includes the input of resources, their consumption, and the output of waste, be converted into cyclic metabolism. In fact, the processes of recycling materials and converting them into reusable materials and energy production for sustainable development of Qarchak city must be measurable in a way that provides better understanding of the complex interactions between the environment, society, and economy.

Author's contribution

Farzad Delivandani and Azita Rajabi developed the study concept and design. Ali Nouri Kermani acquired the data. Farzad Delivandani and Azita Rajabi analyzed and interpreted the data, and wrote the first draft of the manuscript. All authors contributed to the intellectual content, manuscript editing and read and approved the final manuscript.

Informed consent

Questionnaires were filled with the participants' satisfaction and written consent was obtained from the participants in this study.

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Conflict of interest

The authors declare that they have no conflict of interests.

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