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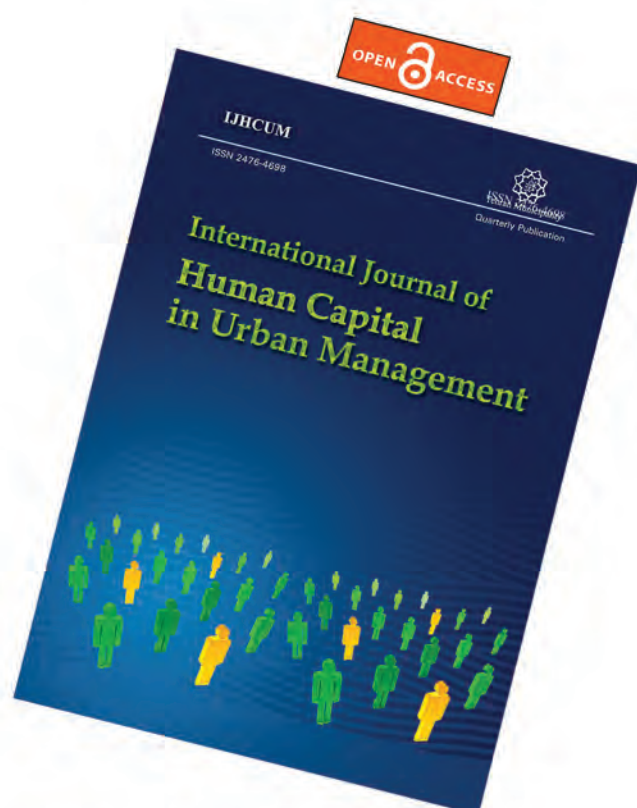
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ORIGINAL RESEARCH PAPER

Architectural analysis and evolution of spaces in mosques in Aleppo City, Syria

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ABSTRACT

**BACKGROUND AND OBJECTIVES:** Since the mosque is one of the most important manifestations of Islamic civilization, it is important to examine its spatial structures. The present study aims to identify the main constituent structures of the spaces in mosques and to investigate how they have changed over time, from the early rise of Islam to the contemporary era.

**METHODS:** It is interpretive-historical research carried out through a case study. The required data are collected using library study and observations. In the present study, Aleppo is selected as the case study due to its significance in Islamic civilization and the originality of the works in it, which have led to the inscription of Aleppo city on the UNESCO World Heritage List.

**FINDINGS:** The research findings are classified into 5 classes including four historical periods of Umayyad, Ayyubid, Mamluk, and Ottoman, and the contemporary era, based on the similarities of patterns. The results indicate the changes in the structures of mosques from functional (especially devotional) combinations of open, roofed, and closed spaces to the merely closed space and the changes in the center of the structure from the courtyard (open space) to the domed Shabistan (closed space).

**CONCLUSION:** The pattern of the worship space has changed from columnar Shabistan to domed Shabistan. Shabistan and minarets are the most stable spaces in the spatial structure of mosques from the Ottoman period to the present. In the contemporary period, roofed and open spaces have transition and service functions, respectively and open spaces are most unstable in the spatial structure of mosques.

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## INTRODUCTION

Since the mosque is one of the most important manifestations of Islamic civilization, it is very important to examine its spatial structures to the extent that some researchers have considered the central mosque as one of the most important features of the Islamic city (Raeesi, 2018). The present study aims to fill the gap in the study of the main constituent structures of the spaces in the mosque (in this research, specifically in Aleppo city) and how they have changed over time, from the early rise of Islam to the contemporary era. So, it attempts to identify applied and original spatial and structural patterns. Although the morphology of Aleppo city has been studied in some studies (Neglia, 2020), the physical and spatial changes in the mosques of this city in different historical periods have been less considered, and this research seeks to fill this gap. Therefore, this research aim is to achieve the original patterns of mosque design in the contemporary period based on historical mosques. The innovation of this research compared to previous research is to have a comprehensive approach to the mosque design issues. Articles such as Architectural Analysis of the First Mosque in Aleppo Using Terrestrial Laser Scanning (Al- Shuaybiyya Mosque) (Orabi, 2020), The destroyed minaret of the Umayyad mosque of Aleppo, the survey of the original state (Fangi and Wahbeh, 2013), Mosque of Bahram Pasha and its endowments in Aleppo, Syria (Abd Al-razik, 2017), etc. have been done by studying single cases of mosques. In this research, the authors have sought to recognize the design pattern of authentic mosques by analyzing numerous historical and contemporary mosques. The importance of this issue in the city of Aleppo is twofold due to the recent damage. In addition, presenting the spatial patterns of mosques of each period can be helpful in the restoration and development of historical sites. In the early mosques the general structure was based on closed and enclosed spaces around the open space of the central courtyard. In some mosques, the mihrab, as an independent volume in the axis of the qibla, protruded from the main shabistan (Erzen, 2011). In the past, there were various types of spaces to respond to various functions in a mosque. Therefore, in addition to being a place for devotion and religious ceremonies, the mosques had social, educational, and political functions and they were a place for rulers'

judgments (Erzen, 2011). Studying the evolution of mosques during the traditional and contemporary periods reveals the evolution of spaces in them and recognizes their original types. Deming and Swaffield (2011) defined typology as the "systematic study of types," which is considered a taxonomic classification scheme. According to them, it is useful to typologize form, structure, arrangement, etc. because "typology seeks to categorize and marshal a vast array of similar but variant design forms and components." Identifying and describing (diagramming) specific qualities and characteristics allow the researcher to establish patterns of associations that relate design elements hierarchically across scales (Deming and Swaffield, 2011). The various types of mosques have been mainly different in space composition and spatial patterns despite having similar types of space. Here, the various types of space include open, closed, and roofed spaces (Fig. 1). According to Haeri (2008) the three elements of ceiling, wall, and floor play active and effective roles in the definition of each type of space. The architectural elements of open spaces are floor and walls, and they are mainly ceiling and floor for roofed spaces, and ceiling, floor, and walls for closed spaces. Each spatial pattern simultaneously has the form, theme, and state (Haeri, 2008; Yigitcanlar and Dizdaroglu, 2015; Teimouri and Yigitcanlar, 2018), so that each spatial pattern is more in line with one of the functions of the building - the mosque. To clarify the difference between the type and the pattern, one can refer to the type of closed space in the mosque, which includes the spatial pattern of the columnar or domed Shabistan. In historical mosques, it has been tried to define a function for each type of space. In the meantime, it is necessary to discuss the factor or factors influencing the spaces in mosques in each period. According to Gideon (2020), the fundamental factors effective in the formation of the building body are stable over a period and distinguish the buildings in each period – here, mosques - from the buildings in other periods (Giedion, 2020).

In the present study, typology is provided based on the type of space, space composition, and spatial patterns of each type. To scrutinize the findings, a table is developed to compare the mosques studied by quantifying the contribution of each type. The mosques belonging to historical and contemporary periods have been analyzed in terms of spatial type to identify original patterns. Therefore, with an

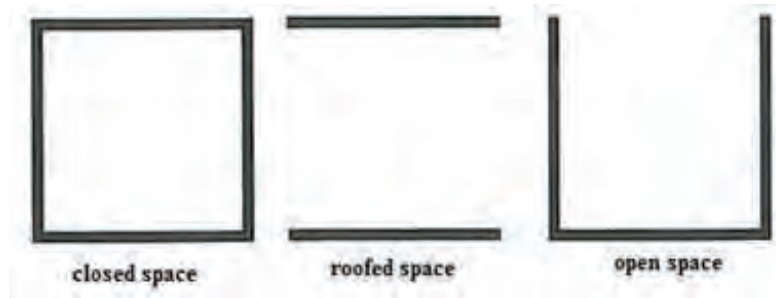


Fig. 1: Horizontal section diagram of various types of spaces (Haeri, 2008)

inductive approach, samples of mosques have been investigated to obtain the spatial patterns of the mosque. The spatial analysis of mosques allows the designers to extract the positive, useful, and efficient features of each type and apply them in their designs. This can be understood in contemporary mosques in which the architecture of historical mosques in Aleppo is modeled. This study has been carried out in Qom, Iran in 2020.

#### MATERIALS AND METHODS

The present study is interpretive-historical research carried out through a case study. The interpretive-historical approach is one of the few methods used to study historical contexts and issues, and this is one of its most important strengths. However, it may have weaknesses due to its interpretive nature (Groat and Wang, 2021). The required data were collected using library study and observations. In the present study, Aleppo city was selected as the case study for some major reasons. First, Aleppo is a world heritage site where there are original and pristine buildings. Second, it is one of the important cities in Islamic civilization, one of the Syrian sites, and the origin of different religions. Thus, it is important to characterize the mosque and differentiate between the places used for worship in each religion in this city. This makes it important to maintain and apply the outstanding and original spatial patterns in mosques in the contemporary era. Third, most studies on the architecture of mosques in Aleppo city are often descriptive and have often addressed the archaeological aspects through case studies (for example, “The two great Syrian Umayyad mosques: Jerusalem and Damascus” is written by Rafi Grafman and myriam rosen-ayalon or “Al-karimiyah mosques in Aleppo, Syria: an architectural and

archaeological study” is written by Mansour Abd al-Razik) rather than providing applied and original patterns. It should be noted that Othman (1992) has carried out valuable studies on the structure and statics of the mosques in Aleppo. While the present study aims to physically and spatially examine the evolution of mosques over time, i.e. from the past to the contemporary era. The plans of Aleppo mosques belong to authentic university documents, including the book “Structural engineering in the mosques of Aleppo” published in the University of Aleppo, the documents of the Aga Khan Foundation in the study of the Historic city of Aleppo, and Islamic countries, and articles of valid scientific-research publications and magazines in the last 13 years for analysis. The case studies were selected from important mosques of each period. Totally, 33 mosques in Aleppo city were selected through screening. The inclusion criteria are including 1. Being original and pristine; 2. Being outstanding; and 3. Being the representative of its period. Therefore, they were selected using a non-probability sampling technique and they were a true representative of a wide range of samples. The historical mosques in Aleppo are divided into four periods: 1. Umayyad mosques including Maqam Ibrahim Mosque on the Citadel of Aleppo (Gonnella, 2008), Al-Rumi Mosque, Great Mosque of Aleppo, and Al-Dabagha Mosque; 2. Ayyubid Mosques including Citadel Grand, Mosque, Al-Shadbakhtiyah Madrasa, and Al-Ṭuranṭaiyah Madrasa (Kameliyyah (Hammad, 2004)); 3. Mamluk Mosques including Al-Rumi Mosque, Altun Bogha Mosque, Al-Ṭawashi Mosque, Al-Aṭroush Mosque, and Bashbougha Mosque; and 4. Ottoman mosques including the Al-Uthmaniyah Mosque, Khusruwiyya Mosque, Ādiliyya Mosque, Bahrāmiyya Mosque, and Īpshîr Pasha Mosque. The contemporary mosques studied include Al-Rawḍa

Mosque, Al-Sabeel Mosque, Al-Siddiq, Al-Shabariq Mosque, Gamal Abdel Nasser Mosque, Usama ibn Zayd Mosque, Al-Rahman Mosque, Al-Tawhid Al-Kabir Mosque, Noor Al-Shuhada Mosque, Salman Al-Farsi Mosque, Al-Ridwan Mosque, Al-Fath Mosque, Al-Ghofran Mosque, Zayd ibn Harithah Mosque, and Al-Anwar Mosque. The most information on mosques is taken from the books "Structural Engineering of the Mosques of Aleppo" and "The Image of an Ottoman City, Imperial Architecture, and Urban Experience in Aleppo in the 16th and 17th Centuries" (Watenpaugh, 2004) as well as Archnet, and Wikimedia sites.

## RESULTS AND DISCUSSION

### *The Architecture of Aleppo mosques, from the Umayyad period to the contemporary era*

In the first centuries of Islamic history, the political and cultural center of the Islamic world was the Fertile Crescent (Palestine, Syria, Iraq), i.e. a place where some of the earliest eastern and western human civilizations emerged and there are significant remnants of ancient cultures. It became one of the points where Islamic art emerged and evolved. The vast territories occupied by the Arabs came under the command of rulers sent from Damascus or Baghdad (Gardner, 2015). Although Aleppo city historically dates back to centuries before Islam and is one of the most historic cities in the Middle East (Burns, 2016), it came under Muslim rule after 661 Anno Domini (AD) and experienced a new period in its history. The Syrian region was the main seat of the Umayyad rulers, so the construction of the outstanding buildings in Aleppo began during this period. The Umayyad era was a time of ostentation of Islam against non-Muslim territories. Thus, these religious buildings competed with other religious buildings such as churches in size and height, and showed their superiority over them (Davies et al., 2009). After this dynasty, different tribes ruled Aleppo. In the present study, those periods with the most influential role in the formation of the architectural style of Aleppo were considered. According to the observations and studies of the outstanding and historical mosques of Aleppo, four periods were found to be the most influential periods: Umayyad, Ayyubid, Mamluk, and Ottoman. It should be noted that some styles were seen in several historical periods but they were placed under one style due to the similarity of applied patterns. Umayyad mosques: The main

factor forming the Umayyad mosques was the rulers' emphasis on the body by which Islam would show its power to Christianity. So, the -mosques were constructed in vast and tall forms (Hillenbrand, 2014). The minarets represented the significance of adhan and salah to prayer and notified local non-Muslims that the new religion was as able as its rivals in designing architectural monuments to glorify itself (Hillenbrand, 2014). The most prominent Umayyad minaret can be seen in the Great Mosque of Aleppo. The five architectural elements in Umayyad mosques that were influenced by the classical, Byzantine, and Iranian architectures are:

- 1) The mihrab or prayer niche (influenced by the chapel at the end of the church);
- 2) The pulpit;
- 3) The royal maqsurah or enclosure (influenced by the special place considered for the royal family in Roman and Byzantine traditions);
- 4) An aisle rising in the middle of the mosque, similar to churches;
- 5) A shabistan and a dome on top of the mihrab (influenced by the Iranian and Christian traditions) (Hillenbrand, 2014).

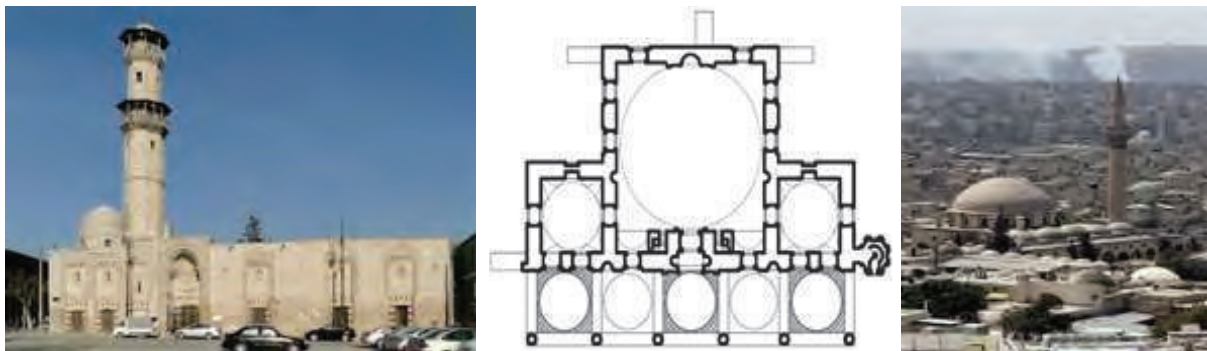
In the Umayyad mosques in Aleppo, the mihrabs protrude from the main volume of the shabistan, and in some cases, this is so significant and visible so that the mihrab itself is built as a separate domed structure, as seen in the Great Umayyad Mosque. What distinguishes the Umayyad mosques in Syria is their resemblance to churches in architecture. Some churches also became mosques during the Umayyad period (Grafman and Rosen-Ayalon, 1999). For example, one can refer to the Great Umayyad (Fig. 2a) and Al-Rumi mosques, which were churches. It is necessary to pay attention to the fact that the qibla direction in Aleppo is south. Therefore, the axis of the qibla in mosques is perpendicular to the east-west axis of churches. So, the longitudinal axis in the rows becomes the transverse axis. Accordingly, one can understand the sensitivity of choosing the site and changing the use of the church to the mosque. Moreover, this change of function naturally brought changes in the organization of spaces in the original buildings of the churches (Gokalp and Uguz, 2018).

Ayyubid mosques: The main factor forming Ayyubid mosques was the rulers' emphasis on and the public's will for those mosques where they





Fig. 2: Courtyard, a- Courtyard, The Great Umayyad Mosque, Aleppo, Syria (Fangi and Wahbeh, 2013),  
b- Courtyard, Al-Firdaws mosque-madrasa, Aleppo, Syria (Hammad, 2004)



Fig, 3: a- Al-Atroush Mosque, Aleppo (Gagnon, 2010), b- Earring layout (Hassan and Mustafa, 2013) c- Ādiliyya mosque, Aleppo (Guillaume, 2010),

could learn religious science. So, smaller mosques were built with the function of mosque-madrasa in most neighborhoods and the minaret height was greatly reduced. These mosques, which were built in Aleppo during the second half of the 13/7 century, are exemplars of Ayyubid architecture. Mosque-madrasas were built on a small scale to serve a local religion and meet local needs. Some of them have a praying room with rib vaults. For example, one can refer to Al-Firdaws (Fig. 2b), Kameliyah, and Sharafiya madrasa in Aleppo (Hillenbrand, 2014).

Mamluk mosques: The main factor forming Mamluk mosques was the emphasis on the vastness and being roofed (Hillenbrand, 2014). The general characteristic of the Mamluk mosques is the variety of minaret forms (Othman, 1992) (Fig. 3a). These tall minarets were built next to the entrances of mosques and were one of the outstanding features of Aleppo mosques in this period. These mosques were also scattered in the residential areas and this is one of the differences between the Mamluk Turks and the

Ottoman Turks in the mosque construction tradition (Blair and Bloom, 2017).

Ottoman mosques: The main factor forming the Ottoman mosques was the presence of a huge closed space for worship rituals, being a landmark, and the landscape of the mosque on an urban scale (Hassan and Mustafa, 2013). Early Ottoman mosques were constructed in the form of a courtyard-free mosques with a columnar shabistan and domed ceilings on all aisles. Later, a porch or portico was added to the mosque and located in front of the shabistan (Based on Hillenbrand's images). A huge gunbadkhane forms the basic pattern of the early Ottoman mosques. Then, the earring pattern, including a gunbadkhane and two rooms on the sides of the mosque, plus a portico on a platform, become a common pattern (Hassan and Mustafa, 2013) (Fig. 3b). The evolved model of Ottoman mosques includes a central courtyard with porticoes around the courtyard and a large domed shabistan on the qibla-facing side. The shabistan has a central gunbadkhane surrounded by



Fig. 4: Al-Rahman mosque, Aleppo, Syria (Kevorkmail, 2010)

semi-domes (Hillenbrand, 2014).

The Ottomans were conservative in their design of minarets (Fig. 3c). The Ottoman minarets resembled a pointed pencil and, in a sense, a spear, as the symbol of the tradition of the Prophet Muhammad (Hillenbrand, 2014). The Ottoman mosques of Aleppo were mainly located on commercial and caravan sites. In this period, one can see the combination of mosque architecture with educational, commercial, residential, and service uses in a complex. Therefore, the buildings built in this period are often in the form of complexes.

**Contemporary mosques:** The main factors forming contemporary mosques are the huge closed space for worship rituals and the symbolism of the mosque on an urban scale. The architecture of most contemporary mosques follows Ottoman-style mosques; Therefore, the spaces in the mosque are organized around a domed shabistan. In the mosques of this period, the closed space has priority over everything, and the most possibility of praying in closed spaces is provided. The pattern of the closed space is often similar to the gunbadkhane pattern of the Ottoman mosques or the three-part pattern of the Ayyubid mosques. Due to the change in the urban block system, in many cases, the mosque site is not in the qibla direction. Therefore, in practice, open space is the remaining space around the main shabistan, which is usually used as a green space or service space (Fig. 4). In addition, in some mosques, various geometries and combinations have been used to compensate for the mismatch between the qibla and site shape.

#### Analysis of case studies

##### Umayyad mosques

*Types of space:* In the Umayyad mosques of





Aleppo, there is a central courtyard (open space) surrounded by closed and roofed spaces. In general, Umayyad mosques have two structures: a central courtyard and a courtyard with an L-shaped roofed space on its two adjacent sides. Also, all types of space, i.e. closed, open, and roofed spaces, have devotional functionality (Table 1a). In Umayyad mosques, the shares of spaces in the total area of the mosque indicate that closed space has a higher priority than open and roofed spaces and it is the widest space with the devotional function, followed by the open space (courtyard for prayers, especially Friday prayers). In total, the courtyard is organized and it has a spatial identity. There is usually a pond or a Wudhu Khana (roofed type) in its center. Over time, the importance of the closed space has decreased and the importance of the roofed space has gradually increased (Fig. 5).

*Spatial patterns:* The main micro-spaces of Umayyad mosques include the main shabistan, courtyard, surrounding porticoes for holding prayers or passing, and minaret, which are located in a centripetal, and enclosed structure (Table 2a).





*Main shabistan:* The Umayyad mosques have a columnar shabistan. This type of shabistan is in a form of an elongated rectangular along with its sides there are columns. In addition, there is a mihrab in the middle of the shabistan and a pulpit next to it, which in most Umayyad mosques, independently protrudes from the main volume of the shabistan. Also, the main space of the shabistan includes a stone dome on its top at the intersection of it with the mihrab and the ceiling of the rest of the shabistan was constructed in the form of the groin vault. *Courtyard:* It had a rectangular geometry with a transverse elongation,

Table 1: The share of open, closed, and roofed spaces in the total area of historical mosques






a- The shares of open, closed, and roofed spaces in the total area of Umayyad mosques

Umayyad mosques	Al-Rumi Mosque	Maqam Ibrahim Mosque	Great Umayyad Mosque	Al-Dabagha Mosque
Mosque plan				
Open space (%)	24.05	25.30	44.55	35.85
Closed space(%)	43.06	74.70	48.59	49.66
Roofed space(%)	32.86	0	6.64	14.54






b- The shares of open, closed, and roofed spaces in the total area of Ayyubid mosques

Ayyubid Mosques	Citadel Grand Mosque	Al-Shadbakhtiyah Madrasa	Al-Ṭuranṭaiyah Madrasa	Al-Firdaws mosque-madrasa
Mosque plan				
Open space (%)	18.03	40.52	15.65	9.34
Closed space(%)	48.28	45.99	62.58	69.94
Roofed space(%)	33.69	13.49	21.77	29.94

c- The shares of open, closed, and roofed spaces in the total area of Mamluk mosques

Mamluk mosques	Al-Rumi Mosque	Altun Bogha Mosque	Al-Ṭawashi Mosque	Al-Aṭroush Mosque	Bashbougha Mosque
Mosque plan					
Open space (%)	27.50	18.95	44.56	18.44	0
Closed space(%)	51.68	25.07	28.27	42.37	100
Roofed space(%)	20.83	15.45	27.16	39.19	0

d- The shares of open, closed, and roofed spaces in the total area of Ottoman mosques

Ottoman mosques	Al-Uthmaniyyah Mosque	Khusruwiyya Mosque	Ādiliyya Mosque	Bahrāmīyya Mosque	İpshîr Pasha Mosque
Mosque plan					
Open space (%)	41.09	58.80	55.54	51.92	43.92
Closed space(%)	34.15	28.08	35.37	34.64	50.42
Roofed space(%)	24.75	13.08	9.09	13.54	5.66

□ open space    ■ roofed space    ■ closed space

which is suitable for holding prayers, especially Friday and Eid prayers. There is a pond or a Wudhu Khana in the middle of the courtyard.

**Portico:** In the Umayyad era, porticoes were used to reduce the effects of hot climates and were of great importance as a roofed space for prayers. The portico of Al-Dabagha Mosque also has a mihrab. In other cases, such as the Great Umayyad Mosque, the

depth of the portico is high and it is designed like the main columnar shabistan. The porticos often have a groin ceiling and its façade facing the courtyard have false arches between the columns.

**Entrance:** In Umayyad mosques, the entrance is not defined as a special space. In the churches converted into mosques, the entrances are often established on the middle axis of the porticoes. In



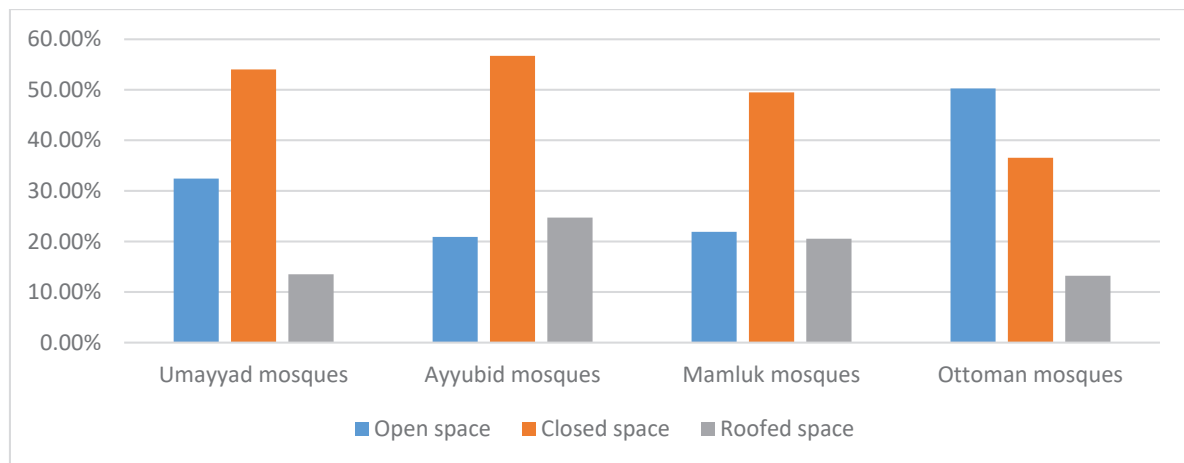


Fig. 5: The share of open, closed, and roofed spaces in the structure of the selected historical mosques

some mosques, such as the Great Umayyad Mosque, separate entrances are provided for people and government officials.

**Minaret:** In this period, the minarets were constructed tall and had a square or circular cross-section. They were located in the right corner of the main shabistan in the qibla direction.

#### Ayyubid Mosques

**Types of space:** Ayyubid mosques are composed of closed and roofed spaces around a square or rectangular open space in the qibla direction. The closed space is a three-part gunbadkhane and the roofed space includes the portico and huge porches (madrasa: a place for education). Coherent and diverse designs in the space composition in Ayyubid mosques are not seen in the mosques constructed in other periods in Aleppo (Table 1b). In Ayyubid mosques, closed space has a much higher priority over open and roofed spaces. In Ayyubid mosques, the spatial hierarchy of open, roofed, and closed spaces is observed in space composition. These mosques have a firm geometry in their plans with a centripetal and axis/diameter-based organization. In Ayyubid mosques, the roofed space has experienced a great change in its spatial pattern so that the quality and quantity of spaces have changed and gotten new bodies and functions (Fig. 5).

**Spatial patterns:** The micro-spaces of Ayyubid mosque-madrasas include the main shabistan,

student rooms, transit portico, Madrasa porch (iwan) (Jarzombek *et al.*, 2011), minaret, and entrances, which are located in an axial-central organization. In this part, the students' room is not addressed because it is not observed in all samples (Table 2b).

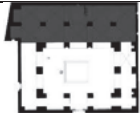
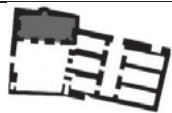



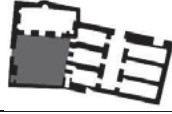
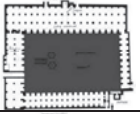


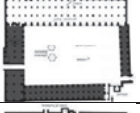




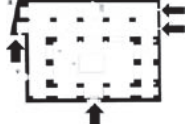
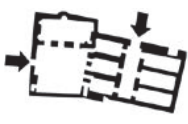
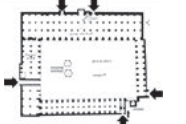

**Main Shabistan:** In Ayyubid mosques, the rectangular shabistans have become more proportionate and the three-part shabistan pattern has dominated the space design. In this rectangle, the middle square has a dome and the two rectangles on its sides have a domed, rib, or semi-domed ceiling. In these mosques, the mihrab is more decorated compared to that in the Umayyad mosques.

**Portico:** Except for the Citadel Mosque, whose portico can be used for prayers, the porticoes of the other Ayyubid mosques have only transit and climatic uses. Therefore, the depth of the porticoes and the column diameter have been reduced and they have a longitudinal elongation due to their transit use.







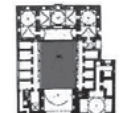


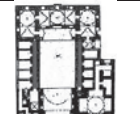


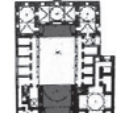


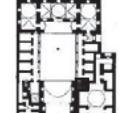



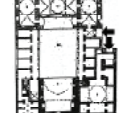

**Porch:** The most important roofed space in the Ayyubid Mosque is the porch, which is designed as a classroom by being closed on three sides and being open to the courtyard. It has a barrel ceiling arch in the qibla direction.

**Courtyard:** It is in the form of a square or rectangle with a longitudinal elongation in the qibla direction. These courtyards can be used for performing prayers. There are various beautiful ponds in the middle of them.

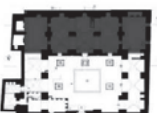



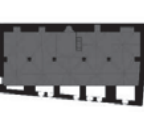
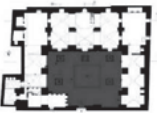



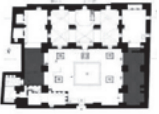







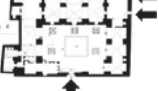




Table 2: Micro-functions of historical mosques *a- Micro-functions of Umayyad mosques*

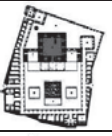
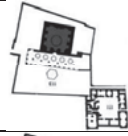
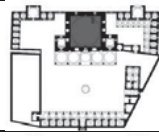
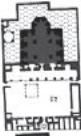

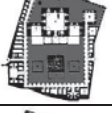
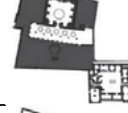
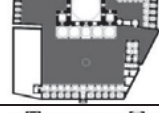


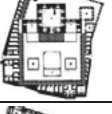
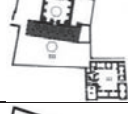
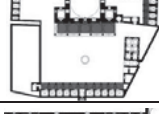
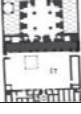
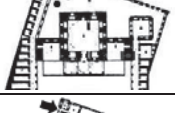
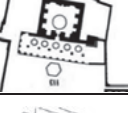
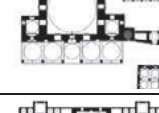

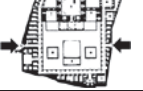

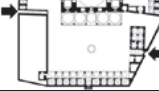


Umayyad mosques	Al-Rumi Mosque	Maqam Ibrahim Mosque	Great Umayyad Mosque	Al-Dabagha Mosque
Main shabistan				
Courtyard				
Portico		No		
Minaret		No		
Entrance				

*b- Micro-functions of Ayyubid mosques*

Ayyubid Mosques	Citadel Grand Mosque	Al-Shadbakhtiyah Madrasa	Al-Turantaiyah Madrasa (Kameliyah)	Al-Firdaws mosque-madrasa
Main shabistan				
Courtyard				
Portico		No		
Porch	No			
Minaret		No		
Entrance				

Continued Table 2: Micro-functions of historical mosques *a- Micro-functions of Umayyad mosques*

c- Micro-functions of Mamluk mosques					
Mamluk mosques	Al-Rumi Mosque	Altun Bogha Mosque	Al-Tawashi Mosque	Al-Atroush Mosque	Bashbougha Mosque
Main shabistan					
Courtyard					No
Portico					No
Minaret					No
Entrance					

d- Micro-functions of Ottoman mosques					
Ottoman mosques	Al-Uthmaniyah Mosque	Khusruviyya Mosque	Ādiliyya Mosque	Bahrāmiyya Mosque	İpshîr Pasha Mosque
Main shabistan					
Courtyard					
Portico					No
Minaret				No	
Entrance					



*Entrance:* In this period, the entrances of mosques are not diameter/axis-based. The entrance is usually next to the porch or porticoes.

*Minaret:* The local scale of the Ayyubid mosques causes the minarets to be short. Their plan was also changed from the square in the Umayyad mosques to octagonal. During this period, the minarets were located in the right corner of the porch overlooking the courtyard of the mosque.

#### *Mamluk mosques*

*Types of space:* Mamluk mosques, like Umayyad mosques, have a central courtyard surrounded by closed and roofed spaces. Also, all types of space, i.e. closed, open, and roofed spaces, have a devotional function (Table 1c). In Mamluk mosques, the shares of open, closed, and roofed spaces have been greatly balanced. However, the closed space was still more important than other spaces, followed by roofed space and open space, respectively. The open space is an organized courtyard and the general composition of open, closed, and roofed spaces is similar to that in Umayyad mosques. Bashbougha Mosque, which was built in the late Mamluk period shows the change in space composition with the centrality of the closed space. This change of approach, i.e. from the design with the centrality of the open space to the closed space, has culminated in the early Ottoman mosques (Fig. 5).

*Spatial patterns:* The main micro-spaces of Mamluk mosques include the main shabistan, courtyard, the surrounding porticoes for holding prayers or passing, and minaret (Table 2c).

*Main shabistan:* The columnar shabistan is in the form of a rectangle with a transverse elongation. A row of columns is located in the middle axis of the width of the shabistan and there are fewer columns compared to Umayyad mosques. In addition, it has a mihrab in the middle of the shabistan and a pulpit next to it. In most of the main shabistans of Mamluk mosques, unlike the Umayyad mosques, the mihrab is inside the main shabistan. Compared to Ayyubid mosques, in Mamluk mosques, the mihrab is less decorated. Also, at the intersection it and the mihrab, the main shabistan has a stone dome with Muqarnas earrings, and the ceiling of the other parts of the shabistan includes groin vaults.

*Courtyard:* It is in the form of a rectangle with a transverse elongation. It is suitable for holding prayers, especially on special days. There is a pond in the form of a square in the middle of the courtyard for worshipers.

*Portico:* Porticoes, as the roofed space, could be used for devotion and worship. In Mamluk mosques, the depth of the portico is lower than that in Umayyad mosques. The porticos often have a groin ceiling and their facades facing the courtyard have columns with vaults between them.

*Entrances:* In Mamluk mosques, the entrances are often located on the sub-axes. In Al-Rumi Mosque, there are separate entrances for the people and government officials. The entrance is characterized by its recess and it is decorated with Muqarnas.

*Minaret:* The various minarets of this period, like the Umayyad minarets, are tall and like the Ayyubid minarets, have an octagonal plan. One of the main distinguishing features of Mamluk mosques is the location of the minaret next to the portal of the mosque entrance.

#### *Ottoman mosques*

*Types of space:* Ottoman mosques are the culmination of the evolution of spaces in Aleppo mosques. In this period, the closed space of the shabistan was of great importance. The closed space of the roofed portico in front of the main entrance is the central space in the space composition. The earring structure is the most common structure in the Ottoman mosques of Aleppo, which is seen in the Al-Uthmaniyah Mosque, Khusruwiyya Mosque, Ādiliyya Mosque, and Bahrāmiyya Mosque (Table 1d). Open spaces also have a significant share in the total area of the mosque in this period. The irregularity of the open space started in this period. The open space in front of the portico located in front of the shabistan is of importance and the open space behind the shabistan is left without any special design so the Ottoman mosques of Aleppo have no coherent and evolved plan seen in the Ottoman mosques of Turkey (Fig. 5).

*Spatial patterns:* The micro-functions of Ottoman mosques include the main shabistan, main and

secondary courtyards, porticos, minarets, and entrances in a complex with commercial, residential, service, and educational spaces. In this section, the residential and welfare spaces are not addressed because they are not observed in all samples (Table 2d).

*Main shabistan:* The main shabistan is a gunbadkhane with a square plan where the mihrab protrudes from the volume on the main axis. At the end of the period, the shabistan has been constructed in a three-part rectangular form with a transverse elongation in qibla direction, as seen in İpshîr Pasha Mosque.

*Courtyard:* The courtyard in front of the main shabistan has a rectangular geometry with a transverse elongation in qibla direction and there is a garden or pond in its middle. The secondary courtyard with a heterogeneous geometry is located behind or in the corner of the main shabistan and accommodates secondary spaces, such as Wudhu Khana or rooms.

*Portico:* The porticoes of this period are the main pattern of roofed space. They are constructed with a columnar structure and consecutive domed ribs - according to the number of people- on the axis of the entrance of the main shabistan. Also, in front of the rooms, around the courtyards, there are porticos with climatic and transit functions.

*Entrance:* The entrance is defined by the recess and the portal. Some of the entrances are placed in the form of corridors on the main axes of the courtyard and the rest of the entrances are scattered as needed. The entrances are usually located on the main axis of the courtyard or in the corners of the secondary courtyard.

*Minaret:* The minarets of this period with a circular section, a tall height, and a spear-like form, are one of the most different types of minarets in the historic mosques of Aleppo. They are located in the right corner of the shabistan portico, i.e. the place of earrings.

#### Contemporary mosques




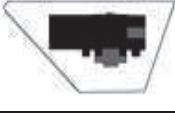






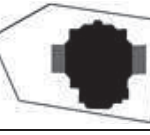




*Types of space:* The greatest diversity of structure

is seen in contemporary mosques of Aleppo. In this period, using Ottoman patterns in the construction of mosques, mosques are usually constructed in the form of a gunbadkhane with a square plan in front of which there is a roofed space in the qibla direction. The preservation of this structure and the varieties of its orientation and shape depend on the shape of the mosque site. Octagonal geometries or combinations of quadrangular geometries, depending on the location, quality, and quantity of the site, the limitations of the financial resources, and secondary functions for the mosque design, are used in sites that are not in the qibla direction. Therefore, the roofed space, according to the proximity of the site and the entrance of the main shabistan, is located in different directions to the shabistan and is not necessarily at the end of the qibla axis. In contemporary mosques, the open space has the least ability for devotional use and often does not have a special organization for performing prayers (Table 3).

The share of the closed space in the total area of the mosque is higher than open and roofed spaces in contemporary mosques. Providing a closed space for holding prayers has been the main goal of architects. At the same time, the roofed space is important as an entrance to the closed space. Therefore, the spatial organization pattern of contemporary mosques, considering the composition of roofed and closed spaces, has been the main issue for contemporary Syrian architects to respond simultaneously to the functions of the mosque and the limitations of the site. In general, if the mosque site is in the qibla direction and it is possible to implement traditional and practical patterns in it, the whole area of the site will be used to build the closed and roofed spaces, as seen in Al-Rawda Mosque, Al-Sabeel Mosque, Al-Siddiq Mosque, and Al-Tawhid Al-Kabir Mosque (Fig. 6).

*Spatial patterns:* In general, the micro-spaces of contemporary Aleppo mosques include the main shabistan, roofed pre-entrance space, toilets, the ladies and gentlemen's Wudhu khana, the guardroom, the Imam's room, minaret, and courtyard. In large mosques, there are service spaces in the corner of the site, a guard room next to the entrance, and the Imam's room next to the main shabistan-the earrings. In some mosques, such as Al-Rahman Mosque and Al-Fath Mosque, there are secondary

Table 3: The shares of open, closed, and roofed spaces in the total area of contemporary mosques

Mosque	Al-Rawḍa Mosque	Al-Sabeel Mosque	Al-Siddiq mosque	Al-Shabariq Mosque	Gamal Abdel Nasser Mosque
Mosque plan					
Open space (%)	0	0	0	65.22	32.86
Closed space (%)	76.87	86.19	79.79	29.40	63.61
Roofed space (%)	23.13	13.81	20.21	5.43	3.53
Mosque	Usama ibn Zayd Mosque	Al-Rahman Mosque	Al-Tawhid Al-Kabir mosque	Noor Al-Shuhadā Mosque	Salman Al-Farsi Mosque
Mosque plan					
Open space (%)	40.94	29.01	0	9.92	20.98
Closed space (%)	46.40	59.82	65.81	66.78	60.46
Roofed space (%)	12.66	11.17	34.19	23.36	18.54
Mosque	Al-Riḍwan Mosque	Al-Fath Mosque	Al-Ghofran Mosque	Zayd ibn Harithah Mosque	Al-Anwar Mosque
Mosque plan					
Open space (%)	63.47	55.91	46.83	50.48	35.76
Closed space (%)	31.14	44.00	49.81	46.58	49.42
Roofed space (%)	5.35	8.62	3.36	2.96	14.825

□ open space    ■ roofed space    ■ closed space

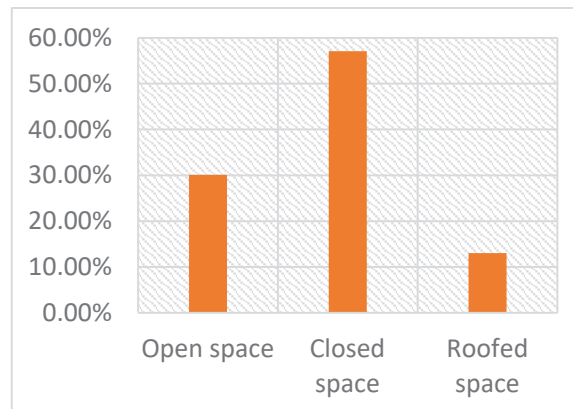


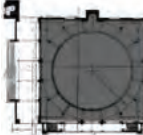

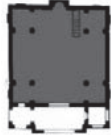

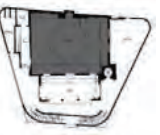


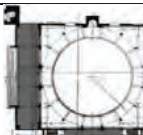

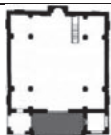
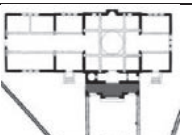

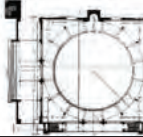

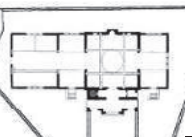
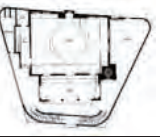
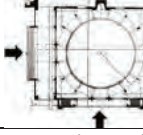


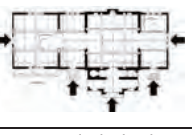
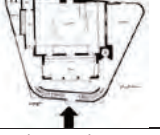
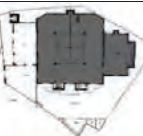

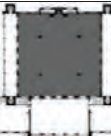

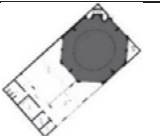


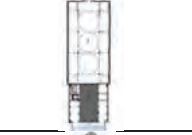
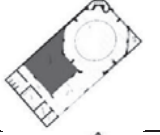



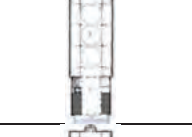
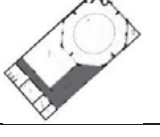



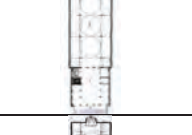
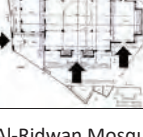



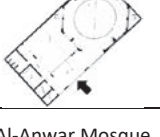
Fig. 6: The share of open, closed, and roofed spaces in the structure in selected contemporary mosques

buildings for secondary functions. These functions include cultural functions such as the library and administrative spaces, welfare-service functions such as resting rooms or dormitories, and educational functions such as religious science classrooms. In

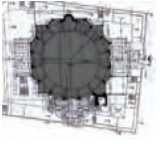


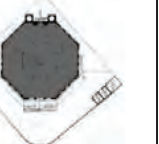
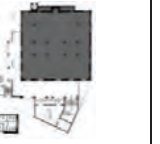





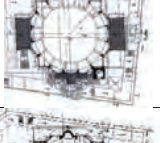




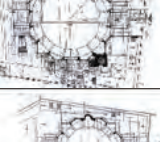
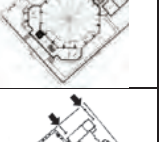


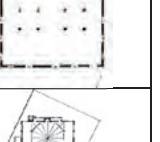

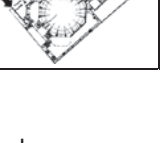

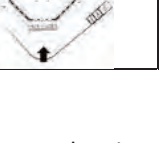
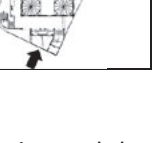
general, due to the comprehensiveness and inclusion of micro-spaces in most contemporary mosques, the main spaces are analyzed and exceptions - as mentioned - are not addressed in the analysis (Table 4).



Table 4: Micro-functions of contemporary mosques

Mosque	Al-Rawḍa Mosque	Al-Sabeel Mosque	Al-Siddiq mosque	Al-Shabariq Mosque	Gamal Abdel Nasser Mosque
Main shabistan					
Courtyard	No	No	No		
Portico					
Minaret			No		
Entrance					
Mosque	Usama ibn Zayd Mosque	Al-Rahman Mosque	Al-Tawhid Al-Kabir mosque	Noor Al-Shuhada Mosque	Salman Al-Farsi Mosque
Main shabistan					
Courtyard			No		
Portico					
Minaret					No
Entrance					
Mosque	Al-Ridwan Mosque	Al-Fath Mosque	Al-Ghofran Mosque	Zayd ibn Harithah Mosque	Al-Anwar Mosque

Continued Table 4: Micro-functions of contemporary mosques

Main shabistan					
Courtyard					
Portico					
Minaret					
Entrance					

**Main shabistan:** Most shabistans have a square plan with a central dome mounted on four columns in the middle of the shabistan. In sites where the axis of the site is not in the qibla direction, a regular octagonal plan is widely used for the main shabistan. In the main shabistans of all contemporary mosques, the mihrab protrudes from the main shabistan. In Al-Ridwan Mosque, the protruded volume of the mihrab is seen along all sides of the octagonal shabistan and is reminiscent of the number of protruded chapels in the churches. Another type of shabistan is the rectangular shabistan with longitudinal and transverse elongations. This geometry is also partitioned into three parts in such a way that it has a domed square in the middle and two rectangles or squares on its sides. For example, the longitudinal elongation in Noor Al-Shuhada Mosque has a three-part pattern in length. The transverse three-part patterns taken from the Ayyubid mosques were used with a slight change in Usama ibn Zayd Mosque, Shabariq Mosque, and Al-Ghofran Mosque and they are effective for separating male and female worshipers.

**Portico:** It is a roofed space located in different

directions depending on the site orientation and the number of entrances to the main shabistan or other spaces. In general, there is one or more roofed spaces as the pre-entrance space next to or along the axis of the qibla of the main shabistan. These spaces have a rectangular geometry with a transverse elongation and they are attached to the main shabistan wall. Its facade has a row of columns and false arches on it. In some other mosques, such as Al-Siddiq, Al-Sabeel, Al-Shabariq, Usama bin Zayd, and Al-Tawhid Al-Kabir mosques, they are closed on three sides - like a porch - and only open to the entrance.

**Courtyard:** In contemporary mosques, the courtyard has no devotional function and the remaining parts are a combination of the site and the mosque building. These courtyards are often used as the green space for mosques. In some cases, such as the Noor Al-Shuhada and Shabariq mosques, the organized courtyard is used to divide the space or as the pre-entrance space for other spaces.

**Minaret:** The minarets of this period have more variety and elegance in design compared to those

of the previous periods, and there are fewer high and bulky parts in them. The minaret of Al-Rahman Mosque can be considered the most daring minaret. The minaret is usually located in the corner of the main shabistan. Most contemporary mosques have a minaret. However, there are exceptions in this regard, for example, one can refer to the Al-Rahman Mosque with six minarets, the Al-Tawhid al-Kabir Mosque with four minarets in its shabistan, and the Zayd ibn Harithah Mosque with two minarets in the two corners of the qibla side.

*Entrance:* The entrance of the main shabistans is more important than the entrance of the site. There is usually an entrance to the main shabistan and an entrance for the secondary functions of the mosque, without any special characteristics. The entrance to the shabistans is a small roofed space, which, of course, is not as strong as the roofed spaces of the portico and porch.

#### *The evolution of types of space*

*The shares of types of space:* The shares of open, closed, and roofed spaces in the total area of Aleppo mosques show that the closed space accounts for the greatest part of the building area. In Umayyad mosques, about 54% of the mosque area is closed space and in Ayyubid mosques, it is 56.7%, and no significant difference in the share of this type of space between these and previous periods. In Mamluk mosques, the importance of the closed space has decreased compared to the previous period. It accounts for about 40% of the total mosque area. In Ottoman mosques, closed space has regained its importance and with a growth of 7%, the share of closed space in the total mosque area has reached 47%. In contemporary mosques, a significant increase in the share of closed space in the total mosque area indicates the priority of closed worship spaces over other spaces. After the closed space, open and roofed spaces are more important, respectively. In Umayyad mosques, the share of open space is higher than the share of roofed space. The open and roofed spaces account for 32.50% and about 13.50% of the total mosque area, respectively. In Ayyubid mosques, the shares of open and roofed spaces in the total mosque area are very close. The importance of the roofed space has increased compared to open space and with an increase of 11% compared to the previous

period, its share in the total mosque area reached 24.70%. The open space is less important than roofed and closed spaces. Its share decreased by 11% and reached about 21%. In Mamluk mosques, the roofed space has become more important and about 30% of the total complex area was allocated to this type. The open space was the least important space, but in general, its share did not change much compared to the previous period. In Ottoman mosques, one can see a change in this structural system and the shares of open and closed spaces are close to each other. In the mosques of this period, compared to the Mamluk period, the share of the closed space increased by 7% and reached 47%, the share of the roofed space decreased by 9% and reached about 11%, and the share of open space increased by 20% and reached 42%. In contemporary mosques, a kind of balance has been established between the three types of space - albeit irregularly and due to environmental determinism. In contemporary mosques, the closed space is more important than that in historical mosques, followed by open space (about 30% of the total mosque area). The roofed space has become less important and its share (13.50%) in the total area of the contemporary mosques is the same as its share in Umayyad mosques (Fig. 7).

#### *Space composition*

In the architecture of historical mosques in Aleppo, attention to the geometry of spaces is of great importance at all quality levels. So, the purity of the geometries of roofed and open spaces is as important as the purity of the closed space geometry. So, first, the traditional architect has applied a variety of methods to simplify and purify all three types of space. This has led users to experience different types of space with different qualities throughout the day in terms of the enjoyment of natural elements such as daylight, airflow, sky view, water, and trees. At the same time, any type of space reveals the hierarchy of functions, distinguishes between main and secondary spaces, and provides the ground for entering the main space. The evolution of spaces in Aleppo mosques shows that the importance of closed space has gradually increased and the importance of open and roofed spaces has decreased. So, their architecture has tended to the use of closed space with the maximum share in the mosque area (Fig. 8). This issue has led to the construction of the mosque with main spaces and the use of the total

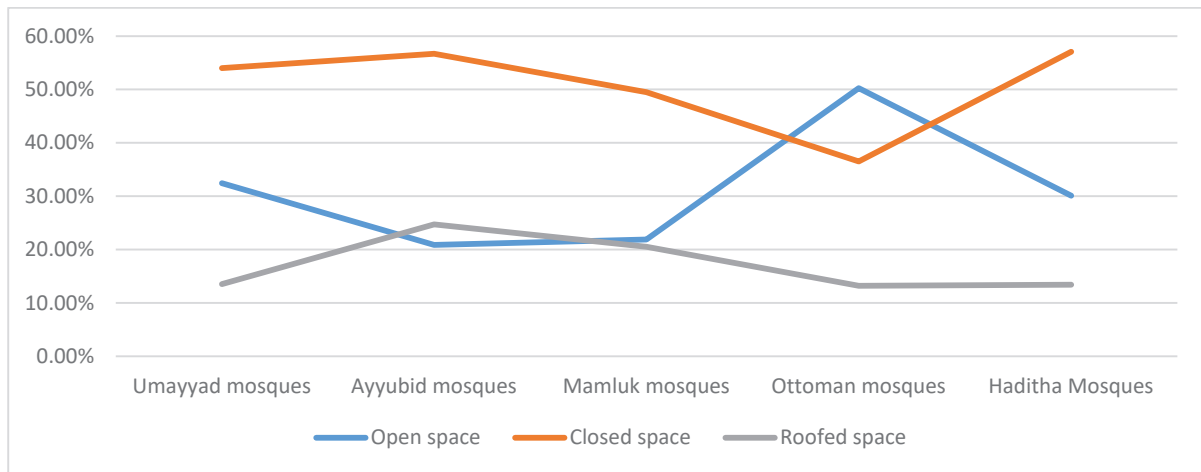


Fig. 7: Evolution of the share of open, closed, and roofed spaces in the total area of Aleppo mosques

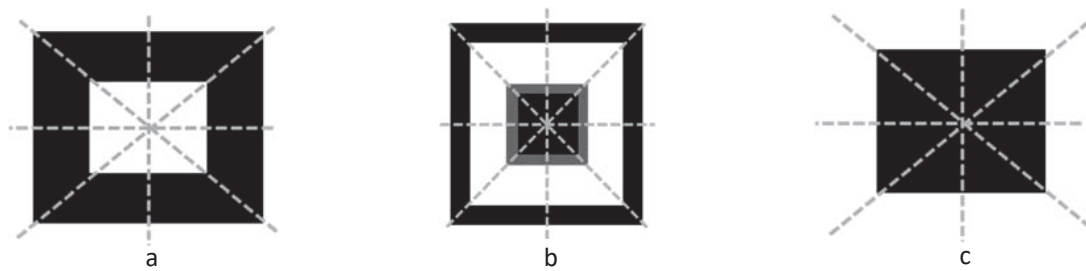


Fig. 8: Structural evolution of types of space in mosques. a- Introverted pattern, b- introverted-extroverted pattern, c- Extroverted pattern

mosque area for the provision of closed space for the main function of the building. In the meantime, the factors affecting the building design, such as climate-friendly architecture, observance of spatial hierarchy, spatial diversity, and provision of beautiful landscapes are inevitably ignored.

#### The evolution of spatial patterns

For the three space types in Aleppo mosques, there are various spatial patterns. The most important issue is the functionality of various spaces for devotional and social functions. In the following, it is discussed how the main spatial patterns of the three space types have changed over time:

**Closed space:** The “Columnar Shabistan” pattern is the most basic pattern in traditional mosques. This spatial pattern consists of a rectangular space with rows of columns that were extended by groin vaults (widely used in Umayyad mosques). Another one is

the three-part pattern in the closed space which was used to connect the three parts. In some cases, one can see a three-part pattern consisting of a central gunbadkhane and two square or rectangular spaces whose longitudinal side is tangential to the main square of the gunbadkhane, and their ceilings are in the form of a dome, semi-dome, or groin vault. The three-part shabistan enhances design flexibility. Therefore, it is possible to expand the shabistan for use when needed (widely used in Ayyubid mosques). The most widely used closed space pattern is the domed pattern. The formal approaches to the domed space pattern have been different. In some cases, the dome is mounted on square space and is surrounded by a wall (widely used in Ottoman mosques). Also, the spatial pattern of the octagonal shabistan with a dome is one of the innovations of contemporary architects to compensate for the difference between the site axis and the qibla direction in Aleppo mosques (Fig. 9).



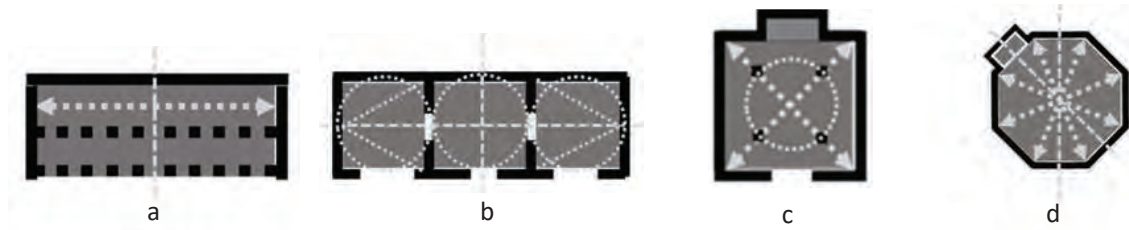


Fig. 9: Evolution of shabistan space. a- Columnar shabistan, b- Three-part shabistan, c- Gunbadkhane with a square plan, d- Gunbadkhane with an octagonal plan



Fig. 10: Evolution of open space, a- Open space in Umayyad and Mamluk mosques, b- Open space in Ayyubid mosques, c- Open space in Ottoman mosques, d- Open space in contemporary mosque

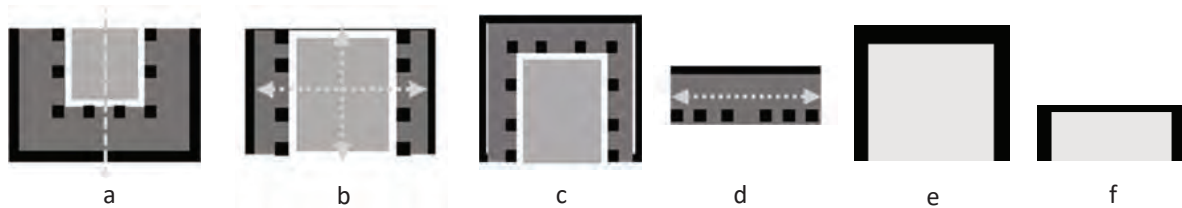


Fig. 11: Evolution of the roofed space of portico, a- U-shaped portico: devotional, b- Linear portico: transition, c- U-shaped portico: transition, d- Linear portico: transition, e- porch: devotional and educational, f- porch: pre-entrance space

### Open space

The central courtyard has been the main space of the historic mosques of Aleppo. This courtyard or courtyard could have religious and social functions in addition to the climatic function and its connection with the natural space. The courtyard was often rectangular or square. In the middle of the courtyard, there was usually a pool or ablution used for purification. From the Ottoman period onwards, green space was considered an air-regulating element and a source of physical and mental comfort, and some Ottoman complexes were designed in the middle of the garden. In contemporary mosques, the open space was limited to the service space or the green space, and the patterns of the central courtyard and open courtyard for the function of worship were practically forgotten (Fig. 10).






### Roofed space

The most stable pattern of roofed space is the porch. Using this spatial pattern began in the Umayyad mosques and has continued until the contemporary era. The porch was initially in the form of a columnar space on which groin vaults were placed in succession and its depth was considerable. After the Umayyad period, the depth of the portico was reduced and the shallowest portico was observed in Ayyubid mosques with climatic and transit functions. After that, in the Ottoman period, the porticos seriously contributed to the external expansion of the closed space. They had climatic and transit functions. They had an entrance to the main shabistan. In contemporary mosques, the portico is used as the most efficient partition space in separate entrances - especially in the walls overlooking the shabistan (Fig. 11a, b, c and d).

Table 5: Summary of the evolution of structural and spatial patterns in Aleppo mosques

Period		Umayyad mosques	Ayyubid mosques	Mamluk mosques	Ottoman mosques	Contemporary mosques
Structural pattern						
		Enclosed introverted	Axial introverted	Enclosed introverted	Axial introverted-extroverted	Axial extroverted
Texture and scale		Natural and residential texture Urban and local scales	Residential texture Local scale	Residential texture Urban and local scales	Commercial texture Urban and national scales	Residential texture Urban and local scales
Micro-spaces	Main Shabistan					
		Columnar shabistan	Three-part	Columnar shabistan	Square gunbadkhane	Gunbadkhane, three-part
	Courtyard or open space					
		Devotional, service	Devotional, service	Devotional, service	Devotional, service, welfare	Service, welfare
	Roofed space					
		Devotional	devotional, educational, transition	Devotional	Devotional, transition	Devotional, transition
	Minaret					
		On the corners of the portico	Next to the porch	Next to the entrance	Next to the portico and shabistan	Next to the main shabistan
	Entrance					
		Non-diameter/axis-based, diameter/axis-based	Non-diameter/axis-based	Next to the minaret, diameter/axis-based	Non-diameter/axis-based - diameter/axis-based	Non-diameter/axis-based-diameter/axis-based
	Secondary function	Sanitary	Educational, residential, sanitary	Educational, sanitary, residential, welfare	Educational, sanitary, residential, welfare, commercial	Educational, cultural, sanitary, welfare, charity

Continued Table 5: Summary of the evolution of structural and spatial patterns in Aleppo mosques

Period	Umayyad mosques	Ayyubid mosques	Mamluk mosques	Ottoman mosques	Contemporary mosques
Example					
	Great Umayyad Mosque	Al-Firdaws mosque-madrasa	Al-Atroush Mosque	Al-Uthmaniyah Mosque	Al-Tawhid Al-Kabir mosque

Another pattern of the roofed space used in the architecture of Aleppo is the porch. The porch is a square or rectangular space that is closed on three sides by walls and one of its sides is open to the courtyard. The porch pattern has been a defined and efficient space in the architecture of Ayyubid mosques for the function of teacher and entrance. The use of the porch is due to its high efficiency in the climate of Aleppo and has been widely used due to the effect that the semi-open space and natural ventilation have on the health of the human body and soul. The use of porches in mosques did not continue after Ayyubid, except incompletely at the entrances (Fig. 11e and f). In general, the study summary of the evolution of structural and spatial patterns in Aleppo mosques is shown in Table 5.

## CONCLUSION

The innovation of this study compared to previous research is to have a comprehensive approach to the mosque design. Previous studies have mostly tried to introduce historical mosques and their visual values. This research is intended to open a path for designers and architects so that contemporary mosques can have diverse spaces for worship. The study of a range of historical and recent mosques has led to the challenges and weaknesses of designing last mosques in the efficient use of open, closed, and covered spaces, with a realistic and critical attitude to find a possible solution to solve these problems in new urbanism. This research has been conducted to achieve the pattern of suitable spatial composition of mosques in the contemporary period. Considering that the city of Aleppo is qualified as World Heritage Site and also needs reconstruction due to the destruction caused by the recent civil war, it doubles the necessity of conducting this research in this city. The research results generally show that recent mosques have been more stable in receiving

and continuing spatial patterns that are more symbolic, such as domes and minarets. While various space types, i.e. open, closed, and roofed space, have been unstable and in decline in terms of space creation and functionality, . The main reasons are the spatial priority depending on the open and roofed spaces, for instance the mismatch between the Gibla and the site. Domed Shabistan is the most suitable response to create great closed spaces. However, the most critical situation of space design can be seen in organizing the open space. In historical mosques, the courtyard has been the main space of worship and the center of the mosque design, but now the closed space is meant as a worship space, and the remaining vacant lots are as open spaces for a service, entrance or garden space. Roofed spaces, which had a religious function in historical mosques, are now dedicated to connecting spaces at the entrances. According to the results, contemporary mosques have been unsuccessful in creating diverse spaces for worship. Therefore by reviving the composition patterns of the open, closed, and roofed spaces, while designing harmoniously with mismatched between the qibla direction and the site, the worship function of the space should also be taken into account. Of course the current conditions of war and insecurity in Syria have caused limitations in conducting this research, and it was not possible to visit the mosques in the field. At future research, these limitations can be reduced with collegial communication and access to documents and discussions with academic professors.

## AUTHOR CONTRIBUTIONS

M. Amirabadi Farahani performed the literature review, analyzed and interpreted the data, prepared the manuscript text, and manuscript edition. M.M. Raeesi performed the research materials and methods, introduction and referencing.

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## CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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## ABBREVIATIONS

%	Percent
AD	Anno Domini
Fig.	Figure

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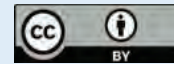
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ORIGINAL RESEARCH PAPER

Determinants of technical inefficiency in solid waste collection service

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ABSTRACT

**BACKGROUND AND OBJECTIVES:** Developing countries have been experiencing a rapid increase in their population. This comes in hand with more human activity and hence increased solid waste generation as one of the by-products. The continuous surge in solid waste generation is a challenge to these countries. Thus the need to make conducive decisions for solid waste management. To achieve this, in 2009, the Government of Tanzania privatized solid waste management services and enacted the Environmental Regulations Law. However, only 20% of solid waste generated in urban Tanzania is collected but instead dumped in landfills. In Morogoro, one of the urban centers in Tanzania, municipal officials can only collect and dispose in landfills less than 35% of the 200 tons of solid waste generated per day. This raises concerns about the technical efficiency of solid waste management and specifically solid waste collection services in Morogoro municipality. The purpose of this study is to measure technical efficiency and analyze the determinants of technical inefficiency for solid waste collection services in Morogoro municipality.

**METHODS:** Primary data was collected using a structured questionnaire with both open-ended and closed-ended questions. Morogoro municipality has a population of 290 waste management agents from whom a sample of 201 was selected using cluster and purposive sampling methods. A stochastic frontier approach was used to measure technical efficiency and analyze the factors determining technical inefficiency. STATA 14 software was used for model estimation and tests.

**FINDINGS:** Results show that technical efficiency for solid waste collection services in Morogoro Municipality is 81.56% that is below the technical efficiency threshold of 95%. Thus solid waste collection services in Morogoro municipality are inefficient. In addition, age of the waste management agent, number of houses participating in waste collection, and number of waste collection tools belonging to the waste management agents are significant determinants of technical inefficiency.

**CONCLUSION:** Results suggest an improvement in solid waste collection through increased wide service coverage. Increased community participation is a necessity and thus mass awareness campaigns are unavoidable. It is appropriate to procurement enough tools and labor force by the solid waste collection agents. Morogoro municipal authority should provide a stern law enforcement process.

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## INTRODUCTION

Rapid urbanization of cities in developing countries may have negative externalities that include among others insufficient collection and improper disposal of Solid waste (SW). Solid waste disposal and collection has become a major concern worldwide (Madinah, 2016). It is projected that global waste will increase by 70% over the next 30 years, that is 3.4 billion tons of waste generated annually. While in Africa waste is expected to increase from 169,119 tons per day in 2018 to an average of 441,840 tons per day by 2025. In Tanzania, municipal waste is expected to increase from 2,425 tons per day in 2012 to 11,566 tons per day by 2025 (World Bank, 2018). Unfortunately, management of Municipal Solid Waste (MSW) is faced with a number of challenges. These include among others lack of financial resources, organization, and complexities due to differences in composition of MSW across municipalities in Africa (Abdel-Shafy and Mansour, 2018). Nathanson (2020) states that Solid Waste Management (SWM) is a process of collecting, treating, and disposing discarded solid materials because they served their purpose and are no longer useful Solid waste collected in sub-Saharan Africa accounts for only 46% of the waste generated. However, in Tanzania less than 50% of people living in urban areas are covered by the waste collection services (World Bank, 2016). In Tanzania, waste management is the responsibility of the urban authorities (Nyampundu et al., 2020). Nevertheless, the Government of Tanzania took different measures to increase Waste Collection (WC) and solve problems associated with uncollected wastes. The environmental SWM Regulations 2009 made under cap 191 of the “2004 environmental management act was enacted to integrate issues of natural resources, public health, and environment in a single legislative framework (URT, 2016; Shimba et al., 2021); Environmental awareness campaign through mass media and public advertisements was done to raise public awareness and community participation in SWM of which every Saturday is a national cleanup day (Lusagalika, 2020); As a result of the amended 2004 Environmental Management Act (EMA), the Tanzanian government got more active in the decentralization of SWM in Tanzania (URT, 2018). This was owing to a rise in

the number of kilograms of solid waste produced, particularly in metropolitan areas (Shimba et al., 2021). The decentralization enabled all Tanzanian local governments, including Morogoro Municipal Authority, to allow Community-Based Organizations (CBOs) and private companies to collect rubbish in each municipal ward. Small Waste Management Agents (WMA) are formed from C.B.Os and private enterprises in each ward to function in every street of Morogoro municipal. Despite all of the precautions taken, Morogoro municipal authorities can collect and dispose of only 35% of the 200 tons of solid trash created everyday. Refuse pits are used to dispose of about 35% of uncollected garbage (Mollel, 2016). Although the Government of Tanzania has tried a number of programs to improve WC, barely 20% of solid waste generated in the metropolitan areas is collected and delivered to landfills. Given that water and sanitation difficulties account for more than 70% of infections detected in Tanzanian health institutions, this situation raises worries about WC in Tanzania (Jumanne, 2019). Borrowing from the Stochastic Frontier Analysis and model (SFA) by Charnes et al., (1978), this may be triggered by WC efficiency of less than 95%, which is a Technical Efficiency (TE) threshold. Higher TE in WC indicates WMA collects the most waste with their inputs, allowing them to collect a higher percentage of waste created. This challenge is exemplified by minimal public participation in WC, as the bulk of the public has no sense of ownership. Even if the media attempted to deliver powerful information for urban cleanliness, it was revealed that many people who migrated from their native/home places and settled in big cities developed a sense of not being at home. This feeling pervades many residents’ brains, making them feel as if they have no control over their settlement environment (Lusagalika, 2020). In the world’s greatest cities, such as Hong Kong, about 70% of municipal solid waste (SW) has been dumped to landfills since 1998, with just around 30% recovered for recycling, implying that more than 99 percent of waste generated is collected annually (Cohen et al., 2015). The world’s most sophisticated cities, such as Paris, are struggling to expand garbage recycling, whereas WC is almost unaffected (Ferrant et al., 2019). There hasn’t been much written about Solid Waste Collection (SWC)

as a separate procedure with an emphasis on the WC service providers' side in Morogoro and/or Tanzania. Several studies focused on waste recycling and Waste Management (WM) as a full process, and one illustrated Morogoro's WC capacity in a nutshell using data from only four WMAs (Shimba *et al.*, 2021). In Morogoro SWC, there is space for significant improvement. The purpose of this study is to provide information on the current condition of SWC in Morogoro as well as solutions for improving WC. Waste treatment and management in developing countries is almost impossible without first improving the WC system, which appears to be a huge problem at the individual household and municipal level due to high population expansion in developing countries (Malata, 2019). The major objectives are to determine how effective WMAs are in collecting solid waste using existing inputs, as well as to integrate and construct inputs (people, garbage collection equipment, and trucks) that will work together to collect the maximum amount of waste possible for each. This will automatically raise the percent of SW gathered, allowing focus on improving the next phases of WM, that is treatment and dumping (for untreatable waste). The goal of this article is to evaluate the amount of TE on SWC services and to investigate the factors that influence WMA technical inefficiency in WC services. The current study has been performed in Morogoro municipality in 2020.

## **MATERIALS AND METHODS**

### *Survey Design and Data Collection*

Using population cluster sampling and purposive sampling approaches, a cross-sectional research design was employed to collect extensive information. Out of the 29 wards in Morogoro Municipality, cluster sampling was utilized to choose 22 with waste management services (Fig 1). The wards were chosen based on their proximity to Morogoro Municipal Center. The respondents in this study, who are representatives of a private company or group responsible for collecting solid waste on selected streets in the Municipality of Morogoro, were from the wards of Kingo, Mji mkuu, Mji mpya, Boma, Sultani, Kihonda magorofani, Sabasaba, Kiwanja cha ndege, Mazimbu, Uwanja wa taifa, Kingurwila, Tungi, Bigwa; Lukobe;

Kilakala; Kichangani; Kihonda; Mbuyuni; Mafiga; Mwembesongo; Chamwino and Mafisa. The WMA were then purposefully selected from each ward/segment of the municipality according to their working streets. 6-15 agents operating in each of the 22 wards/segments (each agent operating in one street) were purposely selected to make a total sample of 201 respondents from a population of 290 WMA. This study used primary data collected from respondents by filling out structured questionnaires and face-to-face interviews. The questions were both open-ended and closed-ended to give an opportunity for respondents to express their opinions and thoughts. The information obtained from the questionnaire was targeted to achieve the objectives of the research. The data was collected between April 15 and May 15, 2020. It is situated between Tanzania's main commercial hub (196 kilometers west of Dar es Salaam) and the country's capital city (260 kilometers east of Dodoma). Morogoro Municipality is located in Tanzania's eastern region (Fig. 1), with a population of 305,840 according to 2012 Census. It is situated between Tanzania's main commercial hub (196 kilometers west of Dar es Salaam) and the country's capital city (260 kilometers east of Dodoma). Furthermore, Morogoro Municipality connects highways for those traveling to Dar es Salaam for business from the central and western regions of Tanzania, as well as those from the southern highlands. As a result, Morogoro municipality has traffic congestion as people link their travels to other regions of the country. The mobility of people and vehicles increases the volume of waste generated in the municipality, necessitating the use of solid waste collection services.

### *Analytical Framework*

In economics, Pareto optimality is the most important valuation principle for efficiency analysis. Efficiency has been well-defined and studied in a variety of ways, including economic, technical, and allocative efficiency. Whereas some studies use randomized control experiments (Amin and Salihoglu, 2020); data envelopment analysis (Jafari *et al.*, 2022) and a meta-analysis (Hoang-Khac *et al.*, 2021) to evaluate efficiency, this study focused on TE to see how WMA use their inputs



to maximize output (waste collected) using the Stochastic Frontier approach (Battese and Corra, 1977). Alvares and Crespi (2003) and Varabyova, and Schreyögg (2013) categorized techniques of efficiency estimation into parametric and non-parametric methods. The parametric methods use econometric techniques based on the assumption that the error term establishes two components. Statistical noise or unpredictability is represented by the first component, while technical inefficiency is represented by the second. SFA, a parametric technique first described by Farrell in 1957 and expanded by Aigner, Schmidt, and Lovell in 1977, was employed in the study. This model is notable in that, in addition to capturing the efficiency term, it also captures the impacts of exogenous shocks that are beyond the control of the units of analysis (Watundu et al., 2021). The Cobb-Douglass production frontier is the simplest and most constrained version of SFA (Battese and Corra, 1977). The Cobb-Douglas

$$Y_i = X_i\beta + (V_i + U_i) \text{ Where } i=1, 2, 3\dots n \quad (1)$$

Where  $Y_i$  is the output or logarithm of production of the  $i^{th}$  WMA,  $X_i$  is the vector of input of the  $i^{th}$  WMA,  $\beta$  is the vector of coefficient to be estimated,  $V_i$  signifies random variables expected to be independently and identically distributed,  $U_i$  signifies random variables assumed to explain technical inefficiency in production and expected to be identically distributed. Parametric models consider the description of production function and state the technological association between inputs and resulting outputs. This is a distinctive feature of this method and an advantage over non-parameter models that do not consider exact forms of production functions generating outputs from inputs used (Coelli *et al.*, 1998). Another potential advantage of parametric models over non-parametric

model is that it accommodates random variations in output and therefore more reliable under normal working conditions. One of the key weaknesses of the parametric model that it is impossible to apply in a small sample size, in addition it can be used to model multiple-output technologies which make it more complex and it entails stochastic multiple output distance functions, and raises complications for outputs with zero values (Charnes *et al.*, 1978). According Lancaster (1966), SFA is an extension of conventional production function approach used to estimate output from production against the value of input which is labor and capital where it is assumed that production is efficient when a producer produces along the production possibility frontier and the production graph only diverges from the frontier due to random shock or an error term which is presented by letter V.

A production function of any WMA can be briefly stated as (Eq. 2);

$$Y_i = f(X_i, \beta) \quad (2)$$

Production can be affected by the degree of efficiency of WMA that can result in less waste collection compared to the planned level. Efficiency can enter production function as (Eq. 3):

$$Y_i = f(X_i, \beta) \varepsilon_i \quad (3)$$

Where  $\varepsilon_i$  stands for the level of WMA efficiency, and it ranges between 0 and 1. If the value is equal to 1, it implies that the WMA has attained optimal output given the technology and all other inputs used in waste collection. If  $\varepsilon_i \leq 1$ , the output is inefficient thus WMA have not utilized their inputs  $X_i$  to their maximum capacity, with the assumption that if output is positive ( $y_i > 0$ ), the degree of TE is also positive ( $\varepsilon_i > 0$ ).

The model is written as (Eq. 4):

$$= + (-u_i) \quad (4)$$

Or in log form as: (Eq. 5):

$$= + v_i - u_i \quad (5)$$

According to assumptions, the mean of this model is a function of independent variables or

people's specific factors. Technical inefficiency could then be described as in given model form: (Eq. 6):

$$= \delta_i Z_i + w_i \quad (6)$$

Calculation of TE was observed by dividing current output by maximum feasible output from minimum resources (Taymaz and Saatci, 1997). Taking into account the substitutions between capital and labor (Reynes, 2019). The function is summarized in natural logarithms as follows (Eq. 7):

$$\ln y_i = \ln \beta_0 + \sum_{j=1}^k \beta_j \ln(X_{jik}) + v_i - u_i, \quad (7)$$

Where;  $y_i$  represents output (SW collected),  $X_{jik}$  is a vector of quantities of inputs used by WMA in (SW) Solid Waste Collection services  $\beta_0$  and  $\beta_j$  are unknown coefficients of parameters to be estimated,  $u_i = -\ln$  is a non-negative one-sided error term associated with technical inefficiency, and  $v_i$  is a random shock, that can capture variation in WMA output due to factors outside its control (It ranges from 0.00 to 0.05). TE can then be presented as (Eq. 8):

$$TE = Y_i = \frac{f(x_i; \beta) \exp(v_i - u_i)}{f(x_i; \beta) \exp(v_i)} = \exp(-u_i) \quad (8)$$

For  $0 \leq Y_i \leq 1$ ,  $Y_i$  is WMA TE rate in providing WC service.

The maximum likelihood technique was used in estimation of the model. The estimated model was also used to determine factors influencing the inefficiencies in SWC. The estimated model was also utilized to find out what factors affect SWC inefficiency. The study used the same function for the model in (Eq. 5) to determine how different parameters (A = Number of households inside the street WMA operations; B = Number of participant houses in waste collection; C = Number of houses with waste separation (sorting) practice; D = Number of waste collection delays; E = Age of waste management agents) influence the amount of technical inefficiency in SWC.  $Y_i = 1$  not only indicates 100 percent efficiency, but it also shows random errors that create deviations from the frontier. These are the deviations from being 100 percent efficient towards achieving target output owing to random effects on the production frontier. Hence justifying

the use of SFA. The study used one-step approach adopted from Battese and Coelli (1995). The approach facilitated the analysis of the determinants of SWC technical inefficiency and computation of TE at the same time. STATA Software (Version 14) was used in analysis. The coefficient was reversed in interpretation since the dependent variable was technical inefficiency and not TE in nature. This means that increasing variables with negative sign increased TE, while increasing variables with positive sign decreased TE. The model was thus specified to include both inputs used and the determinants of technical inefficiency as (Eq. 9):

$$Iny_i = In\beta_0 + \sum_{j=1}^k \beta_j In(X_{jik}) + A - B - C + D + E + v_i - u_i, \quad (9)$$

Where,  $X_{jik}$  is a vector of quantities of inputs used by WMA in SWC services. The inputs used by WMA included (K1= Number of workers in WMA, K2= Number of vehicles used in WC, K3= Number of wheelbarrows, K4= Number of hoes and K5=

Number of shovels where all inputs which could affect WC). A, B, C, D and E were determinants of technical inefficiency in WC.  $Iny_i$  is the output (amount of waste collected).

## RESULTS AND DISCUSSION

### *Descriptive Statistics of the variables used*

The study obtained the measures of central tendency; mean, variance, maximum, and minimum values of variables utilized in the study to define the entire set of data used in the model. (Table 1).

From Table 1, the average of number of houses in each street was 128. This shows that Morogoro municipal has very large number of houses per street and this might hinder proper SWC services. Out of all houses in the street on an average of 44 houses pay for their SWC fees and participate well in SWC. This indicates that a very small number of people are willing to participate in SWC. Number of houses with waste separation (sorting) of recyclable from non-recyclable waste was only 1. This implies that houses do not separate their waste before

Table 1: Descriptive statistics

Variable Name	Description	Observations	Mean	Standard. Deviation	Min	Max
A	Total number of houses in each street of operation for the waste management agents (CBO's/ groups/ private waste management agent with mandate)	201	128	69.4034	25	383
B	Number of participant houses (houses which pay for service on time and collects their houses waste ready for waste management agents per each street)	201	44	21.78459	11	86
C	Number of times the waste collection and dumping process is delayed making waste to still be present in people's houses or in streets	201	1	1.043983	0	3
D	Number of houses which practice waste (sorting) separation in the streets	201	2	1.087102	1	5
E	Age of each waste management agent operating in a street	201	50	10.01403	26	67
K1	Number of workers employed within each waste Management agent	201	4	1.326762	1	7
K2	Number of vehicles used with each waste Management agent in the waste collection process	201	2	1.028282	1	4
K3	Quantity of wheelbarrows employed in the waste collection process	201	3	1.043769	1	5
K4	Number of hoes employed in the waste collection process	201	4	1.299024	2	8
K5	Number of shovels employed in the waste collection process	201	3	1.183615	1	7

Table 2: Technical efficiency of the waste management agents

Observation	Mean	Std. Dev.	Min	Max
201	0.8156659	0.2461313	0.1470303	0.997838

being collected by WMA. On average waste are not collected by WMA 2 times in a month. The mean age of the WMA was 50 years. This implies that WMA are matured enough to know their roles in SWC, and how important their performance is to the community at large. The mean/average number of workers in the WMA was 4 workers. The average number of vehicles used each WMA was 2. This shows a low usage and availability of vehicles for SWC by WMA since, among the vehicles used by every WMA in Morogoro municipal, 1 vehicle is from the municipal council. The vehicle is used to collect the waste from other small collection points of the streets to the dumpsite. The average number of hoes used in WC process was 4. The mean/average number of shovels used in WC process was 3. The mean/average number of wheelbarrows used in WC process was also 3. Generally, few tools were owned by WMA compared to the average number of workers. This showed a low availability and utilization of SWC tools by the WMA since, they had lower average compared to the average number of workers which were 4 workers. This had an impact of number of times waste are collected and the ability to collect waste in all streets effectively.

#### Estimation of Technical Efficiency

Level of TE was estimated (Table 2) and results explains how WMA in Morogoro municipality use the input available to generate the output (kilograms of WC).

The TE score was estimated following Jondrow *et al.*, (1982) procedure in analyzing TE through one-step approach of the SFA. Findings show that the average or mean efficiency is 0.8156659, meaning that the WMA utilized their inputs by 81.56% in WC. Since the estimated TE is less than the efficiency threshold of 95%, this implies that the waste management agents are technically inefficient in WC. SFA was estimated using a one-stop strategy to acquire determinants of technical inefficiency in WC, that comprise estimating TE and analyzing determinants of technical inefficiency in one model

at the same time (Table 3).

The estimated model was proven to be significant, since the Prob> chi2, U sigma, V sigma, Sigma u, and Sigma v were all significant at 1% level. The dependent variable in this model is the nature of technical inefficiency. Kilograms of waste collected per month (Inoutput) was the output variable in this model. Independent variables with a positive coefficient were considered to increase technical inefficiency while, independent variable with a negative coefficient were considered to decrease technical inefficiency. The model provides the frontier regression model containing input variables with the number of hoes having a negative coefficient of -0.1657956 and significant at 5% level. This implies that ownership of one additional hoe will lead to a decrease in Kilograms of solid waste collected by 16.5% if other covariates remain constant. In addition, the number of vehicles had a positive coefficient of 0.1523984 and was significant at 5%. This implies that ownership of one additional vehicle by WMA will increase Kilograms of Waste Collected by 15% if other factors remain constant. Number of shovels had a positive coefficient of 0.3388639 and was significant at 1%. This implies that ownership of one additional shovel by WMA will increase the Kilograms of waste collected by 33.8%, if other factors are kept constant. These results were similar to those of (Lv *et al.*, 2021) in the study of the influences of fixed assets on corporate performance - Evidence from manufacturing-listed companies in China, which found out that growth rate of fixed assets investment had a significant positive relationship with corporate performance manufacturing companies. This could also be interpreted as fixed/capital assets (like hoes, vehicles and shovel) growth rate have significant positive relationship with manufacturing (production) companies. The growth rate of fixed assets refers to the ratio of the annual net increase in fixed assets to the original total fixed assets, which reflects the scale and speed of the growth of fixed assets. Lv *et al.* (2021) also found out



### Technical inefficiency in solid waste collection

Table 3: Results of the determinants of technical inefficiency

Stochastic frontier normal/truncate normal model						
			Number of observations = 201			
			Wald chi2(5) = 60.47			
			Prob > chi2 = 0.0000			
Log likelihood = -67.4536						
InOutput*	Coefficient	Standard Error frontier	Z	P> z	[95% Conf. Interval]	
Constant	9.26821	0.1809012	51.23	0	8.91365	9.62277
lnK1	0.3207087	0.0865642	3.7	0	0.151046	0.490371
lnK2	0.1523984	0.0590766	2.58	0.01	0.03661	0.268187
lnK3	-0.001201	0.0675641	-0.02	0.986	-0.13362	0.131222
lnK5	0.3388639	0.0683955	4.95	0	0.204811	0.472917
lnK4	-0.1657956	0.0706918	-2.35	0.019	-0.30435	-0.02724
Constant	1.177278	0.4396219	2.68	0.007	0.315635	2.038921
A	0.0000514	0.0011332	0.05	0.964	-0.00217	0.002273
B	-0.0802677	0.0172458	-4.65	0	-0.11407	-0.04647
C	0.031624	0.0689019	0.46	0.646	-0.10342	0.166669
D	0.0232851	0.0626924	0.37	0.71	-0.09959	0.14616
E	0.0179992	0.0060459	2.98	0.003	-0.00615	0.029849
Usigma constant	-2.813555	0.6984824	-4.03	0	-4.18256	-1.44456
Vsigma constant	-2.287854	0.1204239	-19	0	-2.52388	-2.05183
sigma_u	0.2449313	0.0855401	2.86	0.004	0.123529	0.485645
sigma_v	0.3185656	0.0191815	16.61	0	0.283104	0.358469
lambda	0.7688568	0.0951803	8.08	0	0.582307	0.955407

\*ln represents natural logarithm of variables used in the model

that the quality of fixed assets had a weak positive relationship with fixed assets. In other words, high quality of fixed asset relatively reduces the cost of operation and increase corporate performance (which is also performance of manufacturing/production companies). This can also imply that, increase in fixed/capital assets like hoes, shovels and vehicles for WMA can relatively reduce the day to day operating costs like these assets' rental costs. The operating cost reduction will go hand in hand with increase of WMA performance in production of solid waste collection service. The number of workers had a positive coefficient of 0.3207087 and significant at 1%. This implies that employment of one more worker by WMA will increases WC by 32%, if other factors remain constant. Similar findings were explained by (Begum *et al.*, 2019) in the study of factors affecting TE of turmeric farmers in the slash and burn areas of Bangladesh in 2019. Results indicated that, training and farm visits of the extension workers have a significant impact on technical inefficiency of farmers in the slash and burn agriculture in Bangladesh. This implies that training significantly improves TE and output of turmeric farming through increasing farmer's

consistency in following the turmeric farming and management practices properly. Similarly, results of the SFA imply that presence of more skilled labor in production of any good or service improves both TE and output of the process. In addition, results in table 3 show that, the significant determinants of technical inefficiency of WC process were; Number of participant houses in the SWC process. Number of participant houses was negative and significant at 1% level with a coefficient of -0.0802677. This implies that increase in the number of participant houses decreases technical inefficiency by 8% if other factors are kept constant. To attain 100% TE, more participant houses are needed, if other factors are kept constant. [Sinthumule and Mkumbuzi \(2019\)](#) had similar results in the study on participation in community-based solid waste management in Nkulumane Suburb, Bulawayo, in Zimbabwe they found involuntary and/or lack of community, participation through voluntary collecting of household wastes ready to be collected by the WMA was among of the factors causing difficulties in SWM. The lack of community voluntary participation in Nkulumane suburb SWC showed 69.6% of the community dumped waste in bins only because

of their fear of fines and punishment not because they perceive it wrong or bad for the environment. It was also found that 20.27 of respondents used to burn their wastes at home. This proves very low community voluntary participation on WC. Similarly, in Morogoro municipal with only 44 houses on average pay for SWC fee on time and get their houses waste ready for collection voluntarily. Age of WMA affected technical inefficiency since it was significant at 1% with a coefficient of 0.0179992. This implies that increase in age of WMA increases technical inefficiency by 1.7%, if other factors were kept constant. This concludes that, younger people performs better in SWC service provision by been able to collect more kilograms of wastes with the use of the same inputs/equipment. Similar results were obtained by Wang et al., (2017), in a study with the title aging and inequality, the perspective of labor income share” conducted, which confirmed the positive relationship between aging and income inequality. The study also showed that the negative effect comes from the shrinking labor force due to aging rather than the lowering of the average wage. This concludes people with old age have lower income share because of lower labor force. Results of this shows that the older the WMA the lower the productivity since there is low will power for work. Similar results were reported in 2020 in the World health organization (WHO) study, that focused on age among the factors of productive capacity. The study concluded that for work in need of strength (like WC), aging deteriorates productivity (World Health Organization, 2020). Contrasting results were reported by (Malata, 2019) in a study titled prediction of amount of solid waste in Morogoro municipality. The main goal was to find right age for people involvement in WC within each house by collecting houses wastes to their bins. It was observed that, older people were better than youths since older people lived longer in their homes to know how to perform home chores. The study had opposite results since it was based on in-house WC only. The work requires little energy, plenty of time with no payment which is suitable for old people as physical exercise. *Log-likelihood ratio test*; These results were also tested for significance by using log-likelihood values through likelihood ratio test statistics (Table 4). This test is recommended

as the best method used to test the relevance of SFA (Kumbhakar et al., 2015). Where  $-2(\text{Restricted log-likelihood value which is the Cobb-Douglas}) - (\text{Unrestricted log-likelihood value which is the stochastic frontier}) = 99.83982$ , that is greater than 5.412 (The Critical value of 1 degree of freedom for the mixed distribution at 1% significance level as reported by (Kodde and Palm, 1986). Thus, the null hypothesis of the inappropriateness of SFA was rejected.

Results indicate that training significantly improves technical efficiency of turmeric farming, consistent with Karthick et al. (2013). The trained farmers are expected to follow the turmeric management practices properly, which might have led to higher efficiency for them.

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Table 4: Results for the restricted log-likelihood test

Iteration 0: log likelihood = -117.37351						
Generalized linear models			Number of observation = 201			
Optimization : ML			Residual df = 195			
Deviance = 37.83836376			Scale parameter = .1940429			
Pearson = 37.83836376			(1/df) Deviance = .1940429			
Variance function: V(u) = 1			(1/df) Pearson = .1940429			
Link function : g(u) = u			[Gaussian]			
Log likelihood = -142.0593524			[Identity]			
OIM			AIC = 1.227597			
			BIC = -996.3061			
Inoutput	Coef.	Std. Err.	Z	P> z	[95% Conf. Interval]	
Consant	7.763791	0.152931	50.77	0	7.464052	8.06353
K1	0.970911	0.080634	12.04	0	0.812871	1.12895
K2	0.193256	0.071857	2.69	0.007	0.052419	0.334093
K3	0.114924	0.083799	1.37	0.17	-0.04932	0.279167
K4	-0.0042	0.09003	-0.05	0.963	-0.18065	0.172258
K5	0.431853	0.086862	4.97	0	0.261608	0.602099

$$= -2*(-117.37351 - -67.4536) = 99.83982$$

Results indicate that training significantly improves technical efficiency of turmeric farming, consistent with Karthick et al. (2013). The trained farmers are expected to follow the turmeric management practices properly, which might have led to higher efficiency for them.

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Results indicate that training significantly improve The model had 201 observations, 0.000 probability meaning the whole set of data was significant and the log-likelihood values through the likelihood

ratio test statistics proved this data's reliability on explaining technical inefficiency in WC.

## CONCLUSION

The objective of this research was to estimate SWC's TE. The fact that WC is the first and most important stage of WM motivated this study. In addition, the study looked into the factors that contribute to technical inefficiency in Morogoro Municipality's SWC. The study used SFA on primary data obtained in Morogoro municipality from April 15th to May 15th, 2020 to achieve these goals. WMA had an average TE of 81.56 percent, according to the findings. The number of homes, cars, shovels, and personnel were important inputs determining the kilogram of SW gathered, while the age of WMA and the number of participant households in WC were major factors with relevant effects on technical inefficiency. These findings indicate that until the year 2020, WC alone was still a significant problem in Morogoro Municipality. Findings from this research will guide policy-makers and environmental managers to design and improve the effectiveness of recycling policies in Tanzania. Globally, this study adds to the literature in order

to lay the groundwork for a successful SWC policy in the same social, cultural, and economic regions and/or states as Tanzania. The findings may also serve as a source of academic knowledge for a better understanding of the SWC process, its TE, and the factors that contribute to technical inefficiency in SWC in Morogoro. The knowledge of TE level in SWC and determinants of technical inefficiency helps SWM stakeholders to know the remaining percent to accomplish reaching TE threshold in SWC and to move on rectifying other phases of SWM. The knowledge of the determinants of technical inefficiency in SWC includes knowledge of how age of WMA and number of participant houses in SWC process affect the technical inefficiency in SWC. Results on age of the WMA show that the younger the WMA the better, indicating more youths are needed in SWC. Engaging more youths in provision of SWC service in the current and future will bring various environmental advantages. The advantages will be coming from positive values found in youths and needed for efficient in SWC which includes more drive, physical strength and good interaction with big part of the community (also mostly youths); Ensure increased long-term efficiency in SWC since youth have more assurance of longer life span than old individuals and reduce all health problems associated with unclean environment since youth will mostly increase efficiency in SWC. Engaging more youth will be more successful if it will coincide with assurance of good and timely payment of SWC fee to the WMA (which is part of participation). This study concludes that the more participant houses the higher the ability for WMA timely fee collection enabling them to call in more youths to engage in SWC service provision. The necessity for higher SWC participation was very clearly indicated by the results. This can be achieved through increased effective sensitization campaigns (both physical ways and through media) as well as practicing reasonable enforcement of law, with the aim of positive effect in SWC participation. The awareness and positive views on SWC participation from the campaign will ensure long-term achievement since every person (children to old adults) will be included.

The government through concerned ministries and other stakeholders may also make a close follow up on how SWC exercise is done by WMA; increase

education on importance of WC, good and timely payment for the service so that all houses can pay for the services on time; supervise WMA in terms of ownership of tools used in SWC; Encourage WMA to keep their data concerning SWC; Encourage more WM campaign's and in-depth yearly researches on WM by higher learning institutions; Provide motivational knowledge, financial and material support to WMA according to their performance in their streets of operation. These changes will be helpful since, municipal council, wards/segments health officers and WMA will be able to; Monitor the efficiency progress of WC and WM work through yearly researches conducted; Know possible determinants of technical inefficiency on WM and how to overcome them. Citizens will also have a chance of providing their opinion of the WM service provided, their level of satisfaction and how they can help to increase WC as part of WM process. Apart from these results there are other areas in need of further research since there is still some literature gapes around SWM and WC areas with respect to Tanzania. Continuous yearly research could be conducted on the technical efficiency and factors affecting technical inefficiency on WC to keep track the progress of the results and if people take measures on the yearly research results. Another research can be on the level of citizen satisfaction from the TE in WC. Another research could be in the role of the government in WC TE. Another crucial area is the Role of Tanzanians University students (researchers) in WM. This is to have a clear picture of how well the researches done can help the society as far as WM is concerned. The research on TE in WC could also be done in different areas (Regions, cities, and towns) in Tanzanian to check if the findings will concur. Other researchers could also research the contributing factors to low participation in WC and/or WM.

#### **AUTHORS CONTRIBUTION**

A.J. Mzava, performed the literature review, data collection, analysed and interpreted data, prepared the manuscript text and manuscript edition. L.A. Chamwali performed data cleaning, interpreted data and manuscript edition. S. Watundu, performed data and results interpretation, proof reading and manuscript editing.



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## CONFLICT OF INTEREST

The authors declare that, there is no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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## ABBREVIATIONS

$\theta_0$ and $\theta_j$	The unknown parameters to be estimated
CBO	Community Based Organization
Conf Interval	Confidence Interval
No of obs	Number of Observation

$\ln$	Represents the natural logarithm of variables used in SFA
SFA	Stochastic Frontier Analysis\Model
SW	Solid Waste
SWC	Solid Waste Collection
SWM	Solid Waste Management
$T\ normal$	Truncated Normal Model
TE	Technical Efficiency
WC	Waste Collection
$u1 =$	$-\ln \varepsilon_i$ A non-negative one-sided error term associated with technical inefficiency.
$v1,$	A random shock, that can capture variation in WMA output due to factors outside its control (It ranges from 0.00 to 0.05).
WMA	Waste Management Agents
WM	Waste Management
$X, jik$	A vector of quantities of inputs used by WMA in WC service.
$Y1$	The term of waste collection output.

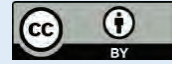
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ORIGINAL RESEARCH PAPER

Identify and prioritize the factors affecting fiscal discipline in Municipalities

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ABSTRACT

**BACKGROUND AND OBJECTIVES:** Global events in recent months, such as the (COVID-19) pandemic, have put pressures on the public budget especially in municipalities that have made it more difficult to understand and measure. Meanwhile, Fiscal discipline as one of the most basic concepts of optimal management of resources and expenditures requires purposeful research and in this regard, the present study was conducted to identify and ranking the factors affecting the fiscal discipline of Municipalities to improve financial aspects of urban management.

**METHODS:** In this research, the mixed exploratory approach has been used so that the qualitative method has played an exploratory role and the quantitative method has played a confirmatory role. Also, in the qualitative stage, the Meta-Synthesis Method and in the quantitative stage, the Shannon entropy method have been used to ranking the factors.

**FINDINGS:** By reviewing 34 studies out of 114 initial studies, researchers identified 14 Indicators and 110 codes as factors affecting the Fiscal discipline of Municipalities mentioned in various studies during the years 2000 to early 2021; identified and categorized in the form of four balanced scorecard (BSC) perspectives.

**CONCLUSION:** The results of this research, in addition to the richness of the literature on the concept of fiscal discipline, assist municipalities in managing fiscal discipline and supervisory institutions in assessments by providing a categorized checklist of factors.

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## INTRODUCTION

In the 1970s, serious efforts were made to improve the financial reporting procedures of public sector organizations. Of course, measures taken in the early twentieth century, especially in the Municipalities of North American States, can be considered the main driver of these developments (Jorge, 2003). Among them, the concept of fiscal discipline was one of the concepts that received special attention. In Iran, too, the history of fiscal discipline goes back to a regulation approved by the Cabinet in 2007. In this regulation, strategies to increase the executive guarantee and strengthen accounting have been approved (Keshavarz and Yazdan Mehr, 2015). According to the Research Center of the Iranian Parliament, the reform of Public sector institutions is one of the main conditions for improving the economic situation in Iran; Because these institutions in the general economic areas of the country play the role of a dominant and monopoly enterprise and affect all economic activities (Midary, 2007); So that Municipalities are expected to play a significant role in achieving the fiscal discipline of the entire country. Regarding the definition of “fiscal discipline”, the general financial literature has no unique definition of fiscal discipline and different authors have used different definitions; the macro dimension is usually considered and fiscal discipline is introduced with three indicators: the ratio of current expenditures to Gross Domestic Product (GDP), the ratio of budget deficit to GDP and the ratio of debt to GDP (Nazarovets, 2001). Fiscal discipline is also defined as the equality of all public revenues and expenditures and the prudent maintenance of debt levels and budget deficits (Pirdal, 2017). Fiscal discipline can be considered from two perspectives: one is the macro perspective in which the government, government officials and the central bank and government agencies and institutions are required to implement fiscal discipline in decision-making and monetary and fiscal policies at the national level and the other micro perspective. In this view, fiscal discipline is considered and implemented at the level of every institution, organization and enterprise that is government or under government supervision (Esfandiari and Dehghan, 2015). This research has been done at the level of Municipalities, which is also considered from a micro point of view. The fiscal discipline of municipalities in this study refers to

fulfilment financial indicators, which are connected with achieving financial robustness and stability of municipal finance. Another concept used in this study is the BSC. The BSC supplemented traditional financial measures with criteria that measured performance from three additional perspectives- those of customers, internal business processes, and learning and growth (Kaplan and Norton, 1996). The BSC was developed by two men, Robert Kaplan, a professor at Harvard University, and David Norton, a consultant also from the Boston area. In 1990, Kaplan and Norton led a research study of a dozen companies exploring new methods of performance measurement. The impetus for the study was a growing belief that financial measures of performance were ineffective for the modern business enterprise. The seminal work by Kaplan and Norton provides a Multi-criteria framework within which performance evaluation can be conducted, termed the BSC. This multi-attribute evaluation concept highlights the importance of nonfinancial attributes. By incorporating nonfinancial attributes into the measurement system of a organization, the BSC seeks to create a wider set of measures that capture not only current performance, but also the drivers of its future performance (Niven, 2006). Concerns about fiscal discipline became a key component of governments’ credit ratings after the 2008 financial crisis (Duygun et al., 2016) and fiscal measures and structural reforms to strengthen long-term economic potential and restore sustainable economic growth are of serious concern to governments (Tkacevs and Vilerts, 2019); some politically motivated managers resorted to financial manipulation to maintain their positions, often leading to fiscal indiscipline and macroeconomic fluctuations (Eklou and Joanis, 2019). On the other hand, according to international polls conducted by the Organization for Economic Co-operation and Development (OECD), public confidence in governments has declined significantly since the recent crises (Organisation for Economic Co-operation and Development, 2017) and there is a serious need for practical monitoring strategies. And the prevention of financial irregularities was felt more than ever. The importance of this issue has led to a continuing emphasis on the concept of fiscal discipline in UN reform reports, including its 2009 report (Blanchfield, 2011). On the other hand, Iranian Municipalities, with a large share of the

country's budget, have a significant role in achieving the country's fiscal discipline and no research has been conducted to investigate the factors affecting the fiscal discipline of municipalities in Iran; As a result, any kind of research that can take a step towards increasing fiscal discipline and economic organization is a special necessity. The purpose of this study is to identify and prioritize the factors affecting fiscal discipline in Municipalities, using the opinions and findings of previous researchers. In this study meta-synthesis has been used to analyze the factors affecting the fiscal discipline of municipalities and the extent and importance of each of the effective factors has been determined using Shannon entropy. The present study is not only new in terms of subject matter, but also innovative in that it examines the issue of financial discipline in the context of BSC and Has identified non-financial factors affecting fiscal discipline in perspectives customer, internal processes, and growth and learning. In other words, this study seeks to fill the gap of previous studies (Macijauskas, 2021; Neto, 2020; Motaleby et al., 2020; Gonzalo et al. 2017; Chowdhury et al., 2016 and Pieschacon, 2012) which usually deal with the macro dimension of fiscal discipline, the micro dimension of fiscal discipline in It has examined the level of Municipalities. On the other hand, the purely economic point of view of most previous researches, this research has used psychological, social, etc. perspectives in identifying concepts and codes. In reviewing a few related types of research, in most cases, the extension method was used or correlation or simple regression tests, and a sample that examined the concept of fiscal discipline by Meta-Synthesis not found (Jalles et al., 2016; Tkacevs and Vilerts., 2019; Jasper et al., 2020). It is expected that this study, by enriching the concepts related to financial discipline, will be able to help the management of municipalities in improving the financial discipline of their respective organizations and improving the studies and planning of regulatory bodies including the Court of Audit, the Audit Organization, the Inspection Organization, the State Planning and Budget Organization, the Ministry of Economic Affairs and Finance, etc.

#### *Empirical background of the research*

Evans (2020) tested the relationship between fiscal discipline, financial development, and economic growth over a 38-year period, confirming

and modeling the multidimensional relationship between fiscal discipline, corruption, economic instability, population size, financial development, and economic growth. Jasper et al. (2020) in their study examined the effectiveness of the budget deficit method on fiscal discipline by examining the fiscal discipline of the European Monetary Union. By examining GDP, they confirmed the direct impact of budget deficit policies on improving financial and disciplinary processes. Shai et al. (2019) aimed to evaluate the degree of fiscal discipline applied in the municipality of Tzwan, South Africa, by examining the variables of accounting and financial auditing skills, length of service and job satisfaction. The results showed a strong correlation between fiscal discipline and the success of projects. Motaleby et al. (2020) in their study entitled "Estimating the shadow economy and tax evasion using government fiscal discipline variables" showed that to reduce the budget deficit and more government fiscal discipline, it is necessary to make the government smaller and reduce spending. Jimenez (2019) also examined the audited financial reports of medium and large cities from 2006 to 2012 and concluded that if citizens had more control over the budget, fiscal discipline in the public sector would improve. In a study, Ekloua and Joanis (2019) examined the impact of financial laws on the fiscal discipline of developing countries. The results of showed a decrease of 1.6% of GDP in the absence of financial laws. In a study entitled "The impact of government borrowing costs on financial discipline," Tkacevs and Vilerts (2019) confirmed the negative effect of interest rate changes on fiscal discipline using financial, political, and macroeconomic variables. Jalles et al. (2016) also examined the relationship between exchange rate policy and fiscal discipline in a study entitled "Exchange rate policies and fiscal discipline". Analyzing data from 79 countries from 1975 to 2012, they concluded that considering the country's conditions and strong exchange rate policy rather than exchange rate stability could lead to greater fiscal discipline. Rahbar and Salimi (2015) also examined the role of government fiscal discipline and the National Development Fund in reducing the Dutch disease in the Iranian economy, and concluded that fiscal discipline is a necessary and sufficient condition to prevent the Dutch disease. In general, the theoretical literature on the subject of research indicates that not much research has been

done on the fiscal discipline of Municipalities and the identification and ranking of factors affecting the fiscal discipline of Municipalities is felt more than ever. The findings of this study facilitating the process of developing guidelines and standards for fiscal discipline of municipalities and will help future researchers to develop concepts of fiscal discipline. The current study have been carried out in Yazd in 2022.

## MATERIALS AND METHODS

The approach of the present study is an exploratory mix so that in the qualitative part the Meta-Synthesis Method is used and in Quantitative part the Shannon entropy technique is used. On the other hand, because the research is designed and implemented shortly after the end of the qualitative research, the present research is a sequential combination.

### Qualitative part of research

#### Meta-Synthesis Method

By providing a systematic approach to researchers by combining different qualitative research, Meta-Synthesis explores new and fundamental topics and metaphors, and promotes current knowledge and creates a comprehensive and broad view of issues. In this study, the seven-step method of Sandelowski and Barros (2007) has been used.

#### Step 1: Set up the research questions

At this stage of Meta-Synthesis Method, the basic questions were asked based on the data in Table 1, and by answering them, the scope of work was determined, until the possible limitations that underlie the possible ambiguities in the later stages of the research are removed.

An appropriate question in Meta-Synthesis can examine a particular phenomenon, its dimensions and consequences and the factors affecting it. If the

research question is too limited and rigorous, it will lead to few studies being identified and reducing the generalizability of the findings. If the question is set too broadly and indefinitely, it may be difficult to draw practical conclusions for the target community (Ridder *et al.*, 2012). The questions of this research are as follows:

- a) What are the factors affecting the fiscal discipline of Municipalities?
- b) What is the classification and ranking of factors affecting the fiscal discipline of Municipalities?

#### Step 2: Literature selection

Past studies and documents have been used to collect research data. These documents include research related to factors affecting the fiscal discipline of public sector organizations from 2000 to 2021. To collect and categorize the content produced in the field of research, refer to Google search engine and scientific databases. A variety of terms such as fiscal discipline have been used to search for related studies, of which a total of 114 were found.

#### Step 3: Search and select the right texts

The researcher deletes a number of studies in each review, which are not reviewed in the Meta-Synthesis process. The review and selection process in this study is summarized in Fig. 1

In this study, after four stages of refinement, out of 114 studies, 80 were deleted and 34 were selected for analysis, some of which are presented in Table 2:

#### Step 4: Extract information

Throughout the Meta-Synthesis, the researcher continuously reviews selected and finalized studies several times to obtain findings within the separate content in which the initial studies are conducted. In the present research, studies information is categorized as follows:

Table 1. The first stage of Meta-Synthesis questions

Explanation parameter	Explanation
(What)	Determining and identifying the components and concepts of fiscal discipline in published studies
(Who)	Various sources (books, articles, parts of books) published in the field of fiscal discipline
(When)	All published studies in the field of fiscal discipline from 2000-2021
(How)	Methods and criteria for resource selection, thematic review of resources, note-taking, analysis, classification and categorization of studied concepts

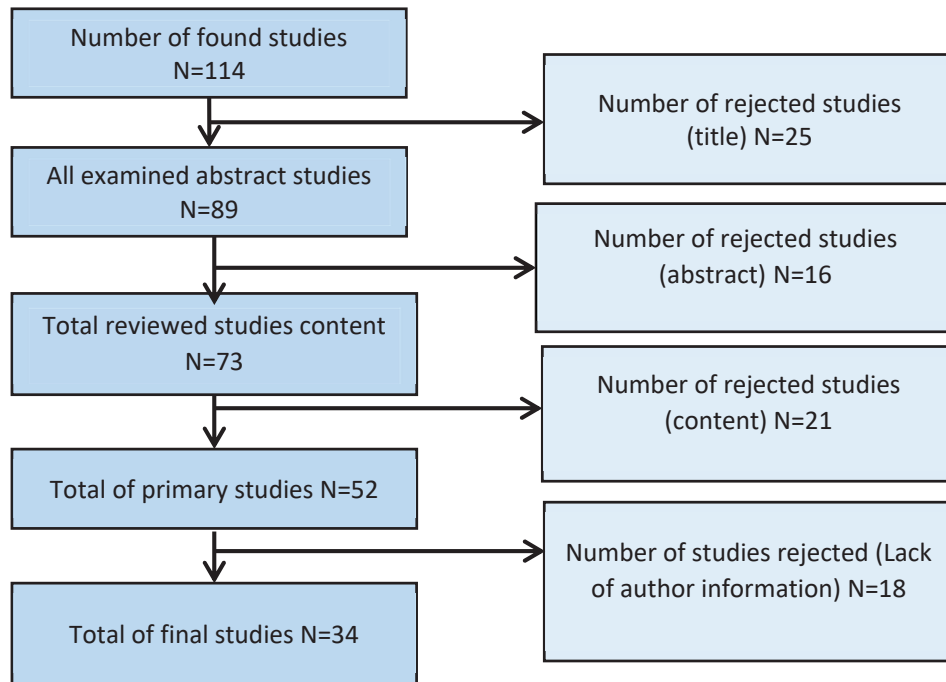


Fig. 1: Review and selection process

Table 2: Some search process findings

Author and Year	Title
Hulsewig and Steinbach (2021)	Monetary financing and fiscal discipline
Al-ahdal <i>et al.</i> (2020)	The impact of corporate governance on financial performance of Indian and GCC listed firms: An empirical investigation
Boehmer <i>et al.</i> (2019)	Raising aid efficiency with international development aid monitoring and evaluation systems
Acerete <i>et al.</i> (2018)	Two decades of design-build-finance-operate roads in the UK and Spain: An evaluation of the financial performance
Chimtengo <i>et al.</i> (2017)	An evaluation of performance using the balanced scorecard model for the university of Malawis polytechnic
Gonzalo <i>et al.</i> (2017)	Fiscal discipline and defaults
Duygun <i>et al.</i> (2016)	The role of sovereign credit ratings in fiscal discipline
Audenaert <i>et al.</i> (2016)	When employee performance management affects individual innovation in public organizations
Hozuri <i>et al.</i> (2015)	Investigating the factors affecting the failure of the failure in the financial control system of executive devices
Kholjigitov (2011)	The role of the fiscal discipline in public finance management in developing countries

a) Research ID: Authors name, year of research publication

b) Note: Extracted components

*Step 5: Analyze and combine qualitative findings*

Step 5 in the Meta-Synthesis method is to analyze

and combine the qualitative findings of the research. During the analysis, the researcher searches for topics that have emerged among the studies in the Meta-Synthesis. Once the codes are identified, the reviewer forms a Indicators and places similar code in the Indicators that best describes it. In this research,



Table 3. Analysis quality control

Analysis quality control indicators	The value obtained
PAO coefficient	0.835
Scott's pi coefficient	0.750
kappa Index	0.760
$\alpha$	0.850

Suitable for Iranian municipalities, all the codes are extracted and an Indicators is defined for similar codes. The resulting concepts were then categorized within the four perspectives of the BSC.

#### Step 6: Analyze quality control

In Step 6, the quality of the Indicators and extracted codes from the previous steps are evaluated. In this regard, four quantitative criteria of Percentage of Agreement Observation (PAO) coefficient, Scott's pi coefficient, kappa Index and Alpha have been used to check the validity, portability, verifiability and reliability, the results of which are presented in Table 3, which are reliable values. The value of these indicators fluctuates between zero and one, and the closer the value of the measurement is to one, indicates the agreement between the results of the researches.

#### Step 7: Present the report and study findings

In this step, the findings of the Steps 1 to 6 are presented. Based on the analysis of 34 final sources for 110 extractive codes, based on the similarity of the codes and after applying the opinion of 3 university experts and 2 municipal financial managers, 14 Indicators including 3 financial concepts, 4 customer concepts, 3 internal process concepts and 4 learning and growth concepts were identified. These results are presented as a comprehensive model in the context of the BSC aspects in Fig. 2. Identifying non-financial influencing factors in Fig. 2 has increased the comprehensiveness of extractive indicators and made the model more practical; the importance of each of the model factors is also presented in a quantitative section.

#### Quantitative research stage

Using Shannon entropy method, the level of support of previous researches for the findings of research is shown statistically.

#### Shannon entropy

According to Shannon entropy method, data

processing is presented with a new perspective and quantitatively. Entropy in information theory is an indicator for measuring uncertainty expressed by a probability distribution. Based on this method, which is known as the compensatory model, the content of the design will be analyzed (Lin, 1991). In this study, after identifying the research factors, Shannon entropy method will be used to analyze the data as follows:

The frequency of each of the identified codes and Indicators must be determined based on the Meta-Synthesis and the desired frequency matrix. For this purpose, the linear normalization method is used in Eq. 1.

$$n_{ij} = \frac{x_{ij}}{\sum x_{ij}} \quad (1)$$

The information load of each factor must be calculated. The Eqs. 2 and 3 are used for this purpose:

$$k = \frac{1}{\ln(a)} \quad (2)$$

$$E_j = -k \sum [n_{ij} \ln(n_{ij})] \quad (3)$$

The coefficient of importance of each factor must be calculated. Each factor has a higher information load, the more important it is. The Eqs. 4 is used for this purpose:

$$W_j = \frac{E_j}{\sum E_j} \quad (4)$$

## RESULTS AND DISCUSSION

In the first step, the decision matrix was formed and the scores obtained from the decision matrix were calculated. Based on this method, the factors that have the most weight also have the most role. The final results of the factors are identified and the rank of each of them is presented in Tables 4 to7; according to the results of the quantitative research

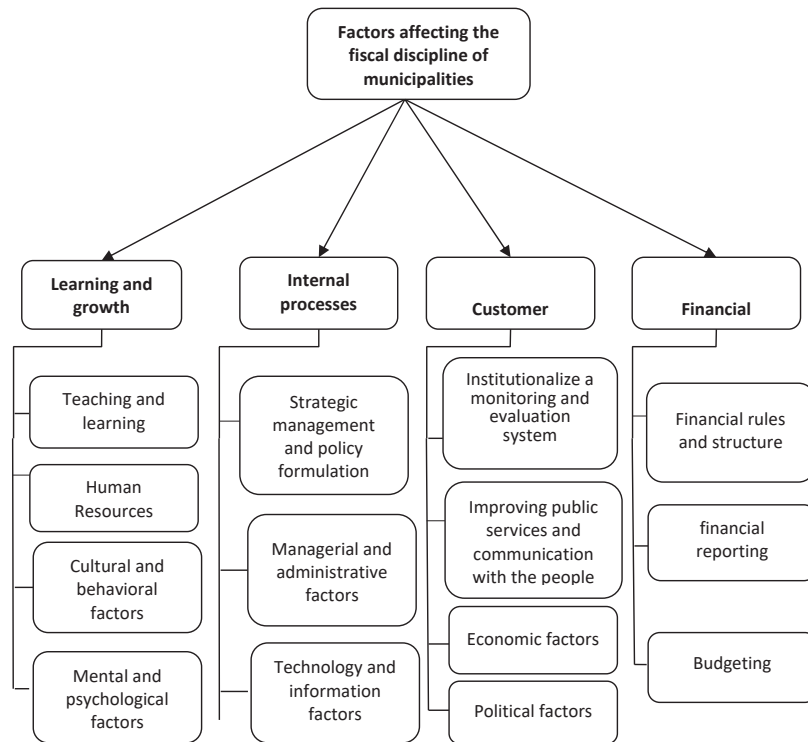


Fig. 2: Comprehensive Model of Fiscal Discipline of Municipalities

section, the perspectives of internal processes, customer, learning and growth, and financial have had the greatest impact on the fiscal discipline of Municipalities, respectively.

#### Financial perspective

Based on the analysis of 14 codes identified in the financial perspective, 8 codes in the Indicators of “Financial rules and structure”, 4 codes in the Indicators of “budgeting” and 2 codes in the Indicators of “financial reporting” are classified and then ranked based on the calculated Weight factor. The results are presented in Table 4. Accordingly, “Eliminate barriers to performing performance audits”, “Management of financial assets and liabilities” and “Implement internal control and strong financial management system” have the highest rank among the financial perspective codes.

#### Customer perspective

Based on the analysis of 43 codes identified in the customer perspective, 16 codes in the Indicators of “Institutionalize a monitoring and evaluation system”,

6 codes in the Indicators of “Improving public services and communication with the people”, 13 codes in the Indicators of “Economic factors” and 8 codes in the Indicators of “Political factors” are classified and then ranked based on the calculated Weight factor. The results are presented in Table 5. Accordingly, “Improving public trust in public sector organizations”, and “Instability and economic shocks” have the highest rank among the customer perspective codes.

#### Internal processes perspective

Based on the analysis of 29 codes identified in the Internal processes perspective, 11 codes in the Indicators of “Strategic management and policy formulation”, 10 codes in the Indicators of “Managerial and administrative factors” and 8 codes in the Indicators of “Technology and information factors” are classified and then ranked based on the calculated Weight factor. The results are presented in Table 6. Accordingly, “Risk assessment and management”, and “Raising awareness and correcting the thinking of managers” have the highest rank among the Internal processes perspective codes.

### Fiscal discipline in Municipalities

Table 4. Ranking and importance factor of financial perspectives codes

Indicators	code	Frequency	Entropy <sub>j</sub>	Weight <sub>j</sub>	Rank in indicators	Rank in code	Rank each indicators
Financial rules and structure	Establish financial rules and regulations	4	0.0086	0.0067	4	73	9
	Management of financial assets and liabilities	7	0.0134	0.0104	2	39	
	Issuance of direct payment authorization by executive bodies						
	Eliminate barriers to performing performance audits	8	0.148	0.0116	1	31	
	Implement internal control and strong financial management system	5	0.0103	0.008	3	63	
	Improve cost management and administrative financial health	3	0.0068	0.0053	5	77	
	Payments are automatic and with a set limit	3	0.0068	0.0053	5	73	
	Check commitments and restrictions on a monthly basis	2	0.0049	0.0038	8	87	
Budgeting	Corporate budgeting	3	0.0068	0.0053	1	77	13
	Standard budgeting in corporate resource allocation	2	0.0049	0.0038	2	87	
	Operational budgeting	2	0.0049	0.0038	2	87	
	Improving the quality and effectiveness of annual budgets	1	0.0027	0.0021	6	103	
financial reporting	Investing in Financial Reporting	2	0.0049	0.0038	2	87	14
	Confidentiality of information	2	0.0049	0.0038	2	87	

#### *Learning and growth perspective*

Based on the analysis of 24 codes identified in the Learning and growth perspective, 6 codes in the Indicators of “Teaching and learning”, 7 codes

in the Indicators of “Human Resources”, 6 codes in the Indicators of “Cultural and behavioral factors” and 5 codes in the Indicators of “Mental and psychological factors” are classified and then ranked

Table 5. Ranking and importance factor of customer perspectives codes

Indicators	code	Frequency	Entropy <sub>j</sub>	Weight <sub>j</sub>	Rank in indicators	Rank in code	Rank each indicators
Institutionalize a monitoring and evaluation system	Retrospective and prospective evaluation	2	0.0049	0.0038	9	87	6
	Internal and external financial supervision	6	0.0118	0.0092	2	47	
	Introduce legal provisions related to monitoring and evaluation	2	0.0049	0.0038	9	87	
	Detailed control of payments and commitments established through financial supervisors	2	0.0049	0.0038	9	87	
	Performance evaluation system	6	0.0118	0.0092	2	47	
	Lack of promotion of demand for evidence of monitoring and evaluation and development of demand-driven programs	3	0.0068	0.0053	7	77	
	Lack of budget related to monitoring	5	0.0103	0.008	6	63	
	Increase employee and manager involvement in monitoring and evaluation	2	0.0049	0.0038	9	87	
	The role of other assessment organizations in monitoring and evaluation	1	0.0027	0.0021	15	103	
	Develop inter-organizational norms and monitoring and evaluation standards	2	0.0049	0.0038	9	87	
	Responsibility for policy, program, performance and process	2	0.0049	0.0038	9	87	
	The relationship between rewards and performance benefits and reporting evaluation results	6	0.0118	0.0092	2	47	
	Reduce financial irregularities and improve efficiency	6	0.0118	0.0092	2	47	

Continued Table 5. Ranking and importance factor of customer perspectives codes

Indicators	code	Frequency	Entropy <sub>j</sub>	Weight <sub>j</sub>	Rank in indicators	Rank in code	Rank each indicators
	Report on budget deduction by reducing violations and holding managers accountable	7	0.0134	0.0104	1	39	
	Improve productivity, transparency and accountability	3	0.0068	0.0053	7	77	
	Government accountability to parliament for law enforcement	1	0.0027	0.0021	15	103	
Improving public services and communication with the people	Proving effectiveness and increasing responsibility for the demands of society	7	0.0134	0.0104	2	39	
	Allocate scarce resources to provide public services	5	0.0103	0.008	4	63	
	Reconstruction of the public sector	5	0.0103	0.008	4	63	
	Explicit requirements for setting public service goals	5	0.0103	0.008	4	63	8
	Increase the power and interest in responding to citizens	6	0.0118	0.0092	3	47	
	Improving public trust in public sector organizations	14	0.0227	0.0177	1	1	
	Cut dependence on heavy and discontinuous revenues and use the open market operation	4	0.0086	0.0067	12	73	
	Justice-oriented economic decisions	5	0.0103	0.008	10	63	
Economic factors	Economic development and poverty reduction	10	0.0176	0.0137	4	12	
	Instability and economic shocks	14	0.0227	0.0177	1	1	
	Linking economic and financial policies in formulating programs and budgets	11	0.0189	0.0148	2	7	
	Lack of monitoring money supply, goods, and capital, Unexpected economic conditions	11	0.0189	0.0148	2	7	2
		9	0.0163	0.0127	6	26	



Continued Table 5. Ranking and importance factor of customer perspectives codes

Indicators	code	Frequency	Entropy <sub>j</sub>	Weight <sub>j</sub>	Rank in indicators	Rank in code	Rank each indicators
	Economic sanctions and the effects of international decisions	10	0.0176	0.0137	4	12	
	Lack of interaction with international professional economic associations	5	0.0103	0.008	10	63	
	Inflation control	8	0.0148	0.0116	7	31	
	Reduce corruption and economic embezzlement	6	0.0118	0.0092	9	47	
	Cost-benefit analysis of economic decisions	8	0.0148	0.0116	7	31	
	Transparency of business environment for domestic and foreign investments	2	0.0049	0.0038	13	87	
Political factors	Governance structure and political authoritarianism	6	0.0118	0.0092	1	47	
	Political considerations and influence in law enforcement	2	0.0049	0.0038	5	87	
	The rule of law and the fight against political corruption	2	0.0049	0.0038	5	87	
	Informal pressures for non-implementation of the system and transparent financial oversight	6	0.0118	0.0092	1	47	10
	Political determination	3	0.0068	0.0053	4	77	
	Reducing the conflict of public interests and political factions	5	0.0103	0.008	3	63	
	Foreign political developments	2	0.0049	0.0038	5	87	
	Strengthening international political relations and political stability	1	0.0027	0.0021	8	103	

Table 6. Ranking and importance factor of Internal processes perspectives codes

Indicators	code	Frequency	Entropyj	Weightj	Rank in indicators	Rank in code	Rank each indicators
Strategic management and policy formulation	Strategic development and planning	7	0.0134	0.0104	5	39	
	Identify the strengths and weaknesses of the organization	10	0.0176	0.0137	1	12	
	Amend the rules for allocating resources within the organization	6	0.0118	0.0092	6	47	
	Commitment to integrity, moral values and the rule of law	3	0.0068	0.0053	11	77	
	Lack of coherence of performance management, strategies and operational goals	6	0.0118	0.0092	6	47	
	Development of combined indicators of structural resources, capital, management systems and human resources	4	0.0086	0.0067	10	73	4
	Strategic roles of each actor in the financial system	5	0.0103	0.0080	9	63	
	Flexibility and risk-taking	8	0.0148	0.0116	3	31	
	Mission, strategic goals, outputs and stakeholders	8	0.0148	0.0116	3	31	
	Strategic goals and operational goals of the organization's budgeting policy	9	0.0163	0.0127	2	26	
	Idealistic and abstract policies	6	0.0118	0.0092	6	47	
Managerial and administrative factors	Risk assessment and management	14	0.0227	0.0177	1	1	
	Effective gesture by managers and incompatibility of managers' powers and responsibilities	8	0.0148	0.0116	8	31	
	Raising awareness and correcting the thinking of managers	14	0.0227	0.0177	1	1	1
	Categorize organizational outputs	9	0.0163	0.0127	7	26	

Continued Table 6. Ranking and importance factor of Internal processes perspectives codes

Indicators	code	Frequency	Entropyj	Weightj	Rank in indicators	Rank in code	Rank each indicators
	Increasing the quality of managers' decisions and their performance orientation	10	0.0176	0.0137	4	12	
	Lack of proper knowledge and insight of performance auditing in the public sector	7	0.0134	0.0104	9	39	
	Delegate authority and achieve work and effectiveness and increase the responsibility of managers	11	0.0189	0.0148	3	7	
	Merit in appointments and decisions of managers	12	0.0202	0.0101	10	46	
	Motivate and provide opportunities	10	0.0176	0.0137	4	12	
	Encourage people to innovate	10	0.0176	0.0137	4	12	
Technology and information factors	Lack of documentation of information and processes	10	0.0176	0.0137	3	12	
	Computer auditing and online systems	11	0.0189	0.0148	1	7	
	Create an independent database for monitoring and evaluation	11	0.0189	0.0148	1	7	
	Systematization and integration of functional information production	9	0.0163	0.0127	5	26	5
	Weak technology infrastructure	10	0.0176	0.0137	3	12	
	Verify performance data and prevent repeated manipulation	6	0.0118	0.0092	6	47	
	Non-transparent information system	3	0.0068	0.0053	8	77	
	Excess bureaucracies	6	0.0118	0.0092	6	47	

Table 7. Ranking and importance factor of Learning and growth perspectives codes

Indicators	code	Weight <sub>j</sub>	Entropy <sub>j</sub>	Frequency	Rank in indicators	Rank in code	Rank each indicators
Teaching and learning	Identify organizational training needs	9	0.0163	0.0127	2	26	7
	Establish knowledge management	12	0.0202	0.0158	1	6	
	Strengthen the specialized skills of auditors in performing operations	5	0.0103	0.008	6	16	
	Attention to education in sector-based budgets	8	0.0148	0.0116	3	31	
	Encourage people to come up with innovative ways	6	0.0118	0.0092	5	47	
	Complete, expand and coordinate MandE system	8	0.0148	0.0116	3	31	
	shaping methods and tools						
Human Resources	Intelligence capabilities	10	0.0176	0.0137	2	12	3
	Intellectual and analytical competencies	10	0.0176	0.0137	2	12	
	Individual and group communication skills	10	0.0176	0.0137	2	12	
	Inadequate human resource structure and composition	10	0.0176	0.0137	2	12	
	Qualifying and hiring specialized and efficient staff	14	0.0227	0.0177	1	1	
	Training skilled academics and identifying educational needs	10	0.0176	0.0137	2	12	
	Creating a competitive system in attracting efficient and specialized personnel	10	0.0176	0.0137	2	12	

Continued Table 7. Ranking and importance factor of Learning and growth perspectives codes

Indicators	code	Weightj	Entropyj	Frequency	Rank in indicators	Rank in code	Rank each indicators
Cultural and behavioral factors	Spirituality at work	1	0.0027	0.0021	6	103	11
	Lack of commitment to integrity	2	0.0049	0.0038	5	87	
	Creating organizational motivation to adopt a culture of accountability	6	0.0118	0.0092	2	47	
	Resistance to change	6	0.0118	0.0092	2	47	
	National determination to eliminate relationalism	7	0.0134	0.0104	1	39	
	Moral values and the rule of law	3	0.0068	0.0053	4	77	
Mental and psychological factors	Lack of justice and past failed experiences	1	0.0027	0.0021	3	103	12
	Public distrust	4	0.0086	0.0067	2	73	
	Lack of common belief and understanding of communication policies	7	0.0134	0.0104	1	39	
	Positive attitude towards work and human beings	1	0.0027	0.0021	3	103	
	Spiritual thinking	1	0.0027	0.0021	3	103	

based on the calculated Weight factor. The results are presented in Table 7. Accordingly, “Qualifying and hiring specialized and efficient staff”, and “Establish knowledge management” have the highest rank among the Learning and growth perspective codes.

#### Discussion

The concept of “fiscal discipline” has a complex and multifaceted nature; this means that although financial factors have a direct impact on fiscal discipline, the impact of non-financial factors is also inevitable. In this research, considering this complexity has been considered by applying the perspectives of the BSC technique. The results of this study provide a comprehensive view of the factors affecting the fiscal discipline of municipalities, a feature that has been less considered in previous

studies. For example, [Shai et al. \(2019\)](#) in their results mentioned only 3 factors of accounting and financial auditing skills, length of service and job satisfaction as factors affecting the fiscal discipline of municipalities, and [Jimenez \(2019\)](#) in its results, only the role of citizen control in the fiscal discipline of municipalities is considered. The results of studies such as [Alijan and Al-Rabeawi \(2021\)](#) and [Valibeigi et al. \(2020\)](#) have been conducted on the basis of a BSC and to evaluate the overall performance and not just the fiscal discipline of municipalities. According to the results of [Aleksandrova \(2020\)](#) research’s, which is considered as one of the few researches in the field of fiscal discipline of municipalities, economic, demographic and financial factors have been identified as the most important factors affecting the fiscal discipline of municipalities. The present study covers



these results and identifies the economic factor in the customer perspective, demographic factors in the growth and learning perspective, and financial factors in its financial perspective.

## CONCLUSION

Achieving fiscal discipline requires comprehensive determination in various fields, and one of the biggest financial challenges for municipalities and their supervisory institutions is the lack of a roadmap for managing and evaluating fiscal discipline; a map that can show signs of fiscal indiscipline and provide solutions to address them. At the international level, and especially in Iran, the concept of fiscal discipline has not been paid much attention so far, especially at the micro level, and the need for purposeful and operational research is felt more than ever. As a result, the present research tried to play a significant role in paving the way by identifying and ranking the factors affecting the fiscal discipline of municipalities and prepare municipalities to perform their legal duties and submit periodic reports of revenues and expenditures. In this study, using Shannon's entropy and Meta-Synthesis techniques and using 34 different references, the theoretical summary and saturation on the subject of factors affecting financial discipline were discussed. According to the findings of this study, these factors include 4 perspectives: financial, customers, internal business processes, and learning and growth, which consists of 14 indicators and 110 codes. So that the Indicators of "Financial rules and structure", "budgeting" and "financial reporting" in the financial perspective, the concepts of "institutionalize a monitoring and evaluation system", "Improving public services and communication with the people", "economic factors" and "Political factors" in the customer perspectives, the Indicators of "Strategic management and policy formulation", "managerial and administrative factors" and "technology and information factors" in the internal processes perspectives and the Indicators of "Teaching and learning", "human resources", "Indicators" Cultural and behavioral factors" and "mental and psychological factors" were identified in the perspectives of learning and growth. Results of this study indicate that improve fiscal discipline in Municipalities, the technologies and processes of the organization must be optimized in the first step, Plan to meet the needs of the organization's stakeholders in The second step, promoting innovation

and continuous improvement in the third step, and in the last step, improving the previous three perspectives. Will improve financial indicators. Also, "managerial and administrative factors", "economic factors" and "human resources" as the most effective indicators and "Improving public trust in public sector organizations", "Instability and economic shocks", "Risk assessment and management", "Qualifying and hiring specialized and efficient staff", "Raising awareness and correcting the thinking of managers" and "Creating a competitive system in attracting efficient and specialized personnel" have been identified as the most widely used and important codes, they play a significant role in promoting fiscal discipline of municipalities. The above results can help officials and individuals to plan to identify strengths and weaknesses in the field of fiscal discipline of municipalities and efforts to plan and improve it.

## Suggestions

According to the research findings, it is suggested, to pay attention to the following:

- Strengthen the audit committee: Strengthen the audit committee and increase interaction between the financial departments of municipalities to improve the financial and budgetary structure and proper reporting;
- Use of new technologies: Using artificial intelligence tools and management dashboards to evaluate and continuously improve fiscal discipline;
- Supporting whistleblowers: Supporting whistleblowers and Establish a secure communication platform for sending abuse reports to improve public trust in public sector organizations;
- Individual Development Plan: Establishment of a specialized working group for Individual Development Plan to purposefully train existing managers and employees and hire specialized and efficient employees;
- Support for applied research: Utilizing the potential of universities and research centers to provide solutions to address the challenges of fiscal discipline of municipalities and also to address possible problems in the conceptual model of this research.

## Limitations and future research

In this research an attempt has been made to overcome many of the limitations of quantitative and qualitative methods by using a mixed exploratory

approach; The main limitation of our study is that we chose to include most of the studies that met our inclusion criteria, sometimes in spite of quality, and low methodological rigor this was done to include as much available data as possible and issues such as the possibility of bias and prejudices of the researcher may impair the findings and results of the research. Although in the present study, an attempt has been made to obtain more reliable results by achieving theoretical saturation. Also, since in qualitative research, the phenomenon under consideration in the context in which it occurs is investigated; the possibility of generalizability of the results and findings of the qualitative part of the research is limited to other areas. The wide dimensions of the concept of "fiscal discipline" and the limited resources and research indicate that the results of this study can play an important role in addressing this concept in future research. The suggestions of this research for the future are as follows:

- The fiscal discipline model presented in this study is related to municipalities, and it is suggested that this model be considered in other organizations, macro level (national budget) or micro level (individual or family).
- In this research, Meta-Synthesis method has been used, which suggests that the feasibility of other qualitative methods be examined.
- Identifying factors that assess fiscal discipline can also be considered in future research.

#### AUTHOR CONTRIBUTIONS

S.Motahari performed the literature review, analyzed and interpreted the data, prepared the manuscript text. A. Taftiyan helped in the literature review, methodology review and manuscript edition. M. Moeinadin helped with the literature review.

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#### CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism,

informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

#### ABBREVIATIONS

$\alpha$  krippendorf coefficient for Reliability assessment

*BSC* Balanced Scorecard

*CASP* Critical Appraisal Skills Program

*GDP* Gross domestic product

*IDP* Individual Development Plan

*OECD* Organization for Economic Co-operation and Development

*PAO* Percentage of Agreement Observation

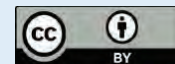
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ORIGINAL RESEARCH PAPER

Providing a lean human resources management model

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ABSTRACT

**BACKGROUND AND OBJECTIVES:** Quick advancement of technology, rising risks, globalization, and expectations for privatization are among the environmental characteristics that current organizations are facing. To be successful in this setting, lean human resources provide a competitive advantage, which its implementation results in the continuous removal of wastes (obstacles) and the high-quality and low-cost providing of services. Therefore, the objective of the current study is to Evaluation of lean human resource management model in the Islamic Council of Tehran. Tehran's City Council as a service organization must reform the structure of Human Resource to increase the skills of employee, so this study aimed to changing the approach of Human Resource Management to Lean and increasing the productivity.

**METHODS:** The present study uses a quantitative approach. This article has a "descriptive-correlational" methodology of the type of "analysis of variance-covariance matrix". In other words, the relationship between variables is analyzed based on the purpose of the research. The survey was carried out in the form of a desk and field research. The research model was extracted via analysis and interpretation of the interviews with the experts of the Islamic City Council of Tehran by employing the thematic analysis method and four rounds of the Delphi technique. Eventually, the measurement model and the structural model to assess the relationships between variables, as well as confirm the developed model, were examined utilizing the data gained from the Islamic City Council of Tehran.

**FINDINGS:** On the basis of the findings achieved from the structural equation modeling, the items "Performance Appraisal" with a factor loading of 0.89, "Employment" with a factor loading of 0.91, "Improvement" with a factor loading of 0.77, "Remuneration" with a factor loading of 0.87, "Supply" with a factor loading of 0.92, "Compensation System (Benefits and Rewards)" with a factor loading of 0.84, "Flow" with a factor loading of 0.76, "Relationships" with a factor loading of 0.79, and "Maintenance" with a factor loading of 0.86 explain the latent variable of the "lean human resource management model in the Islamic City Council of Tehran".

**CONCLUSION:** Results of this investigation have presented a comprehensive model for the evaluation of the lean human resources management in Tehran's City Council that could be exploited by industrialists and scholars. The novelty and originality of the lean human resource management model has not been designed and localized for Tehran's City Council up to now. Therefore, this research enhances the existing knowledge about lean human resource management.

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## INTRODUCTION

Human Resource Management (HRM) is the most key and essential activity in the organization (Giermanowska *et al.*, 2020). HRM has experienced remarkable changes in practices within organizations and theories. Organizations realized that sustainable competitive advantage is accomplished via sound Human Resources (HRs) management (Florén *et al.*, 2014). HRM functions embrace an extensive variety of matters, methods, techniques, and circumstances, leading to multiple implications (Galuszynski and Potts, 2020). Lean human resource management is an approach to increase productivity and continuous value creation and minimize costs and losses (Chahal *et al.*, 2017). Established in the Toyota Production System (TPS), also known as Lean Manufacturing, lean is among the most critical innovations in the domain of management in the twentieth century (Mol and Birkinshaw, 2014). Lean philosophy places a heavy emphasis on waste elimination (activities that absorb and consume resources and reserves but create no value), continuous improvement of processes, and respect for customers, staff, and suppliers, and these items constitute its guiding principles (Shah and Ward, 2007). Generally, there is compliance in relation to the effect of lean on the potential moderating role of HRM practices within the organization (Bocquet *et al.*, 2019). Despite the fact that noticeable improvements of lean practices so far took place in the management sphere, the achieved human dimensions of lean have unexpectedly eliminated attention from the previous academic area (Magnani *et al.*, 2019). “Lean” is actually a universal collection of techniques through which wastes within an organization are eliminated; not only will the organization become leaner, but it will subsequently make the organization more flexible and accountable (Rangsee *et al.*, 2019). Lean is a systematic approach to identify and remove waste (non-value-adding activities) through continuous improvement for attaining perfection. Besides, lean management is an effective and efficient management system that could result in the satisfaction of human forces (manpower). The lean paradigm in the service sector is a novel notion in Iran, which attempts to find waste elimination and value creation in business processes. The design and localization of a LHRM pattern for organizations can lead to the formation of productive HR to proceed in the current competitive and varying conditions. Hence, this directly reflects the essential

requirement and high application of this survey. Taking into account that HR are the most valuable resource of any service organization (Macke and Genari, 2019), so the most critical factor influencing the achievement of success in the city council is manpower. Thus, the establishment and implementation of a lean HR model in this domain can greatly contribute to creating a value-based structure in the City Council. Implementing such an approach in the Islamic City Council of Tehran will result in efficiency and enhancement in the satisfaction of HR. A LHRM model has not yet been designed and localized for Tehran’s City Council, representing the novelty of this investigation. In this respect, the current study intends to explore the lean status of HRM of the Islamic City Council of Tehran, which has currently attracted the attention of many managers in urban management as a hybrid concept. Moreover, this study seeks to investigate what is the LHRM model of Tehran’s City Council? And how lean is Human Resource Management?

### Literature review

Terms of activity in service industries have radically changed during the last two decades (Bryson *et al.*, 2012). Organizations have understood that the solution for advancement in such a competitive and changing atmosphere is staying shoulder to shoulder with change and accepting new conditions. Businesses have gone through multiple paradigm transitions from hand production to mass production to the present day and are now moving beyond lean manufacturing (lean production) (Martínez-Jurado *et al.*, 2014). Evidently, organizations are composed of something more than organizational charts. The essence of organizations is shaped on the basis of diverse resources such as human, financial, material, and information resources and knowledge (Norouzifard and Zamani, 2016). As Mathis and Jackson (2010) expresses: “Managers are responsible for combining and coordinating these various resources to achieve the organization’s goals”. Nevertheless, HRM is regarded as a vital function for organizations (Anwar and Abdullah, 2021) since the key component shaping the organizations are people and effective management of them is the central duty of HRM (Florén *et al.*, 2014). The cornerstone of HRM studies should be recognized in scientific management (or Taylorism) and the human relations movement (Jenkins, 2019). Among the scholars, who exploited time and motion studies (or time-motion study) from



the perspective of the tasks of each job to develop the best way of doing the job were Taylor and Gilbert. As [Mathis and Jackson \(2010\)](#) state, the origins of HR function should be considered in the growth of the size and complexity of organizations, which resulted in the establishment of specialized units for the recruitment of new employees and then the appropriate management of the existing labor force. The majority of initial investigations in connection with the theoretical literature of HR greatly emphasized practical topics, and orientations led to the individual level. The primary preludes of contemporary orientations in the field of HRM, nevertheless, lies in the content of early research ([Allen et al., 2016](#)). These preliminary studies founded the theoretical basis of research relating to HRM, as pointed out by [Wright and McMahan \(2011\)](#) and [Huselid \(2018\)](#). As Wright pointed out, these preliminary studies formed the theoretical basis of HRM research. Furthermore, the contribution of organizational theorists and their role to strengthen the theoretical foundations of HRM studies, e.g., [Katz and Kahn \(1978\)](#) and [Miles et al. \(1978\)](#), could not be overlooked. This is because this type of thinking is on the rise in most current theoretical literature so that the position of managing the employee affairs has been converted to a strategic partner, and its centralized and staffing function has become the decentralized and queuing function, and HRM concept embraces all management decisions and activities, which somehow influence individuals (or HR) in the organization ([Arfmann and Barbe, 2014](#)). Manufacturing companies of Japan, particularly in the automotive sector, encountered the challenge of shortages of raw materials, financial resources, and HR after the Second World War. To deal with this situation, Eiji Toyoda and Taiichi Ohno at Toyota Motor Corporation in Japan were the pioneers in introducing the notion of TPS, which was later recognized as lean manufacturing in the United States ([Miller and Patterson, 2018](#)). The core idea behind the TPS was waste elimination. Anything that did not create added value to the final (finished) product from the customer's viewpoint was seen as a waste. The primary goal of lean production was to assist manufacturers who were willing to upgrade their company's operations and acquire more competitive advantage through the implementation of diverse lean tools and techniques. For the first time in 1988, John Krafcik employed the term "lean". [Krafcik, J.F., \(1988\)](#) exploited the term lean

for the elaboration of the TPS ([Netland et al, 2016](#)) because the system used the least of anything in comparison with the mass production model, the inventor and the pioneer of which was Henry Ford ([Brophy, 2013](#)). [Womack and Jones \(2003\)](#) also presented the summary of the results of their review in the well-known book "the machine that changed the world: The Story of Lean Production" to the world, in which they announced the reasons for the success of the Japanese and the way of their functions in various dimensions. By the dissemination of the results of [Womack and Jones \(2003\)](#) study, the lean idea was rapidly welcomed so much in the United States, for American corporates perceived that the Japanese carried out the design, development, production, and distribution of their products utilizing half of the resources (generally human, investment, workspace, tools, raw materials, time, and expense) relative to American companies. In a study entitled "Customer-focused lean production development", [Kosonen and Buhanist \(1995\)](#) examined a customer-focused lean production model. To facilitate the transformation of organizations into lean organizations, the authors focused on changing structures, formations, and methods, viewing an organization, and training multi-skilled personnel. In their study, [Nightingale and Mize \(2002\)](#) developed a maturity model for transformation of lean enterprises. [Joyce and Schechter \(2004\)](#) assessed the philosophy of lean enterprise management. In the study of [Johnson et al. \(2012\)](#), the main areas of focus for transforming organizations into lean organizations included developing a common perspective, designing a smart annual system, providing specific instructions by top coaches, linking the cost of problems and outcomes to root causes, creating visual cues, teaching problem-solving and knowledge transfer skills, creating a physically and emotionally healthy environment, promoting progress through supervision, and assigning tasks to emerging leaders. [Tekez and Taşdeviren \(2016\)](#), presented a model for assessing the leanness capability of companies. [Tajpour \(2018\)](#) investigated the effect of knowledge management on improving manager's skills. In addition, [Hosseini et al. \(2020\)](#) investigated the effects of entrepreneurial skills on manager's job performance. A lean organization could be regarded as an organization, in which lean principles and flexibility prevail in all its actions and activities ([Sanders et al, 2017](#)). The principal idea in a lean organization is that

all the activities of the organization such as leadership, management systems, production planning and control, and other activities should be conducted in a lean way as much as possible. In accordance with the definition offered by [Womack and Jones \(2003\)](#), a lean production system is “a system that utilizes all inputs more efficiently and minimally to create the same output that a conventional mass production system generates while enhancing diversity for the end customer”. What is required by customers is manufactured in the maximum needed quality and quantity with the minimum cost and the shortest possible time by employing the lean approach. Definition of [Jordan and Michel \(2001\)](#) of a Lean Organization includes a network organization that a company forms with its strategic partners so that it could promote its capability to convey value to its customers by developing the resources and capabilities of the company in the form of a business partnership network. All partners and the company in some way create added value for the company’s end product on the basis of this definition. In their opinion, the essential activity of the lean organization is identification, correction, and recreation of the value flow. Value flow contains activities throughout the business network that create added value for the end product from the customer’s perspective ([Wan and Frank Chen, 2008](#)). Lean production of a measure is not a function or a reaction; however, it is a process. Lean management is a systematic approach to identifying and eliminating (removing) waste via continuous improvement of product flow with customer attraction, which looks for achieving perfection ([Tortorella et al, 2016](#)). Among the researchers conducted in this field are [Kosonen and Buhanist \(1995\)](#) entitled “customer focused lean production development”, [Nightingale’s \(2002\)](#) entitled “development of a lean enterprise transformation maturity model”, [Joyce and Schechter \(2004\)](#) entitled “the lean enterprise-A management philosophy at Lockheed Martin”, [Johnson et al. \(2012\)](#) entitled “from Toyota to the bedside: nurses can lead the lean way in health care reform”, [Tekez and Taşdeviren \(2016\)](#) entitled “a model to assess leanness capability of enterprises” pointed out in this regard. Because the developing HRM is a novel and evolving discussion, and the benefits of its incontrovertible attainments travel the path of evolution and development, hence, this is a new debate among

Iranian managers and scholars. In accordance with the conducted literature review, lacking coherent and fundamental models to advocate the application of lean thinking in the HRM development is felt, which, this gap is explored in this investigation. One of the most critical factors influencing the achievement of success in the city council is manpower. Thus, the establishment and implementation of a lean HR model in this domain can greatly contribute to creating a value-based structure in the City Council. The current study has been carried out in Tehran City Council and 2021.

#### *Conceptual Model*

After writing the research design, literature review and evaluation of the existing models in the area of “LHRM” were conducted. To this end, keywords such as models available in the field of HRM, lean management, and LHRM were exploited. Next, in-depth interviews with the experts of Tehran’s City Council (senior managers of the Islamic Council of Tehran and Professors and academic experts) were conducted. In this respect, after the extraction of codes from the research literature, interviews were done with experts to specify codes, which were ignored in the literature review. In order to analyze and extract the components of LHRM, the Thematic Analysis (TA) method was employed. Cohen’s kappa coefficient was used during the code identification process to measure inter-rater agreement. The coefficient was measured for the identified themes. In this study, the kappa coefficient was calculated as 0/86, indicating very good inter-rater agreement. Finally, after four rounds of the Delphi technique, the conceptual model of the research was extracted in the form of the [Table 1](#).

#### **MATERIALS AND METHODS**

The present study uses a quantitative approach. The research method is descriptive-correlation and according to the classification of [Sarmad et al. \(2014\)](#) is the type of analysis of variance-covariance matrix. The survey was carried out in the form of a desk and field research. This means that the desk research in relation to “LHRM”, literature review, and theories in connection with the subject were initially performed. After identifying the indexes, a questionnaire was distributed among the experts of the Islamic City Council of Tehran, and the completed questionnaires were returned. Then, examining the distribution

Table 1: The domestic model of LHRM

Criteria	Code	Index
Performance Appraisal (P)	P1	Showing proper feedback
	P2	Innovative performance appraisal systems
Employment (E)	E1	Cultural preparation
	E2	Staff involvement in continuous improvement
	I1	Enhancing productivity
Improvement (I)	I2	Staff training
	I3	Competency-based succession planning
	I4	Job rotation
Remuneration (C)	C1	Giving suitable rewards
	C2	Creativity and innovation
Supply (S)	S1	Attracting multi-skilled employees
	S2	Meritocracy
	S3	Competency-based selection
Compensation System (Benefits and Rewards) (A)	A1	Providing welfare and medical services to staff
	A2	Payment system based on performance
Flow (F)	F1	Staff empowerment
	F2	Developing the scope of staff responsibility
	F3	Socialization process
Relationships (R)	R1	Developing relationships on the basis of mutual trust and commitment
	R2	Group coordination and decision-making
Maintenance (M)	M1	Low-level management
	M2	Workplace conditions
	M3	Appropriate job promotion path
	M4	Aligning the objectives of individuals and organizations

normality of the studied statistical sample utilizing Kolmogorov-Smirnov (KS) test via SPSS 20 software. Eventually, the offered conceptual model was analyzed using SEM with the aid of LISREL 8.80 software. In order to assess the reliability of the research tools, Cronbach's alpha method was applied. After the distribution of the questionnaire, the value of Cronbach's alpha for the study's questionnaire was obtained to be 0.973. As this value is greater than 0.7, the questionnaire reliability was confirmed. The "content validity" was employed for checking the questionnaire validity. Content validity makes guarantees that all dimensions and components, which could reflect the desired concept in which there is a kind of measurement, are considered. Initially, after formulating the initial framework of the questionnaire, the viewpoint of 10 senior managers of Tehran's City Council was assessed for its evaluation, and its validity was approved. In order to achieve the sample size, Cochran's formula was exploited Eq. 1 (Momeni and Ghaioimi, 2007):

$$n = \frac{N \cdot (Z_{\alpha/2})^2 \cdot \delta^2}{\varepsilon^2 (N - 1) + (Z_{\alpha/2})^2 \cdot \delta^2} \quad (1)$$

For a 45-item pretest sample, the value of standard

deviation was estimated to be 0.73851. Thus, the sample size is computed by Cochran's method as follows:

$$n = \frac{250 \times (1.96)^2 \times 0.73851}{(0.05)^2 \times (250 - 1) + (1.96)^2 \times 0.73851} = 205.016 \approx 206$$

With respect to the statistical population number (250 people from the staff of Tehran's City Council), the statistical sample size was estimated to be 206 persons based on the formula of sampling from the limited population. The random sampling method was exploited in this survey.

## RESULTS AND DISCUSSION

### Results of the research

For data analysis, inferential statistics techniques were applied. After examining the distribution normality of the studied statistical sample utilizing KS test, using SEM, the relationship between the sub-dimensions and the latent variables is initially assessed for each of the model dimensions by employing Confirmatory Factor Analysis (CFA) in the form of measurement models. Next, the relationships between the dimensions of the model are investigated in the form of a structural model. The hypothesis examined in

Table 2: The results of the KS test to check the distribution normality of the questionnaire

KS test		LHRM model in Tehran's City Council
Mean	Normal parameters	2.58
Standard deviation		0.74032
Absolute	Most Extreme Differences	0.177
Positive		0.177
Negative		-0.109
	Kolmogorov-Smirnov Z	0.691
	Asymp. Sig. (2-tailed)	0.748

a. Test distribution is Normal.

this study is that the items "Performance Appraisal (P)", "Employment (E)", "Improvement (I)", "Remuneration (C)", "Supply (S)", "Compensation System (Benefits and Rewards) (A)", "Flow (F)", "Relationships (R)", and "Maintenance (M)" explain the latent variable of the "LHRM model in the Islamic City Council of Tehran". For checking the normality of the distribution of the components constituting the model, the KS test was exploited (Momeni and Ghaioimi, 2007). The results of evaluating the relevant hypotheses are in the order of Table 2:

$H_0$ : Data has a normal distribution.

$H_1$ : Data has a non-normal distribution.

The results of Table 2 present the number of data, the desired parameters in examining the existence of distribution (like mean and standard deviation in a normal distribution), the absolute value of the maximum deviation, the maximum positive deviation, the maximum negative deviation, the Z-statistic value, and the of significant number value (sig), respectively.  $H_0$  hypothesis is accepted since sig is greater than 5%, so the claim indicating the normality of data distribution is approved. Among the statistical modeling techniques, which has recently entered from the behavioral sphere to the field of management, organization, and economics is the SEM same as the regression, the quantification of relationships between independent and dependent variables is conducted in this approach. However, structural parameters express causal correlations dissimilar to regression parameters that exhibit experimental correlations. The conceptual model of measuring "LHRM in the Islamic City Council of Tehran", representing the relationship between the latent variable and the observed variables, is illustrated in Fig. 1:

With regard to the results of CFA, significant

numbers in the form of Fig. 2 were gained as follows:

As indicated in Fig. 2, all significant numbers associated with the items of the measurement model are significant, for their significant number is higher than 1.96. Therefore,  $H_1$  is confirmed. The model fit indices represent that the model is at a desirable condition in terms of the fit index because its chi-square to the degree of freedom ratio is equal to 1.75, which is less than the standard error value 3, and the Root Mean Square Error of Approximation (RMSEA) is equal to 0.096, which is less than the standard error value 0.1. Hence, many modifications are not required. The P-value is less than 0.05. The optimal value of the goodness-of-fit index (GFI) in this model is equal to 0.95 (more than 0.9), and the Adjusted Goodness of Fit Index (AGFI) is equal to 0.86 (more than 0.8). The standard estimation model of "LHRM in the Islamic City Council of Tehran" is as follows Fig. 3:

In accordance with Fig. 3, the measurement model of any of the model dimensions, including "Performance Appraisal", "Employment", "Improvement", "Remuneration", "Supply", "Compensation System (Benefits and Rewards)", "Flow", "Relationships", and "Maintenance", was explained. Besides, the relationships between observed and latent variables in Tehran's City Council were confirmed, and the fit indices were assessed to be at a favorable level. Furthermore, the following results for each of the model dimensions were achieved according to Fig. 2:

➤ The most essential sub-dimensions in the dimension "Performance Appraisal (P)" with a factor loading of 0.89 were "Innovative performance appraisal systems (P2)" with a factor loading of 0.83 and "Showing proper feedback (P1)" with a factor loading of 0.79, respectively. In today's ever-changing and complex environment, organizations need to modify and improve their performance evaluation systems through innovation to grow and survive.



Fig. 1: The conceptual model of "LHRM in the Islamic City Council of Tehran"

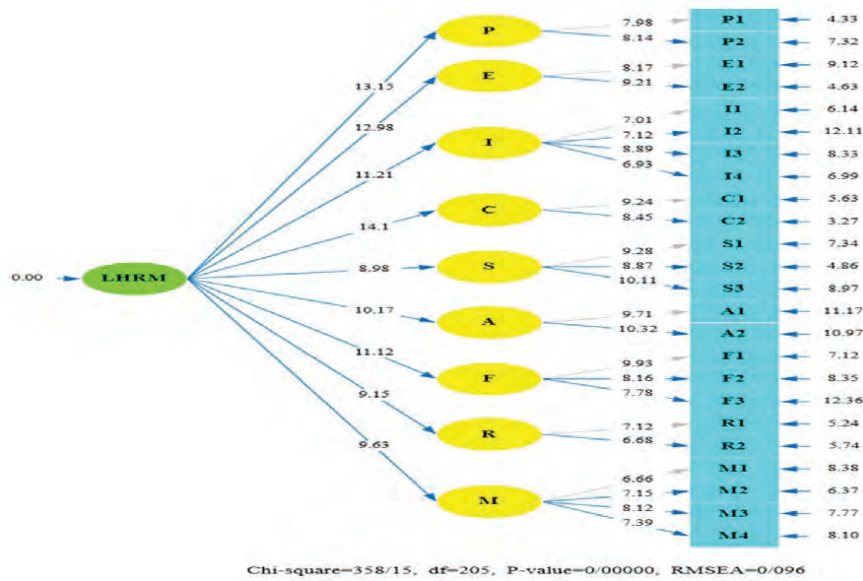


Fig. 2: Results of the significant numbers relating to the "LHRM model in the Islamic City Council of Tehran"

➤ The most critical sub-dimensions in the dimension of employment with the factor load of 0.91 were the staff involvement in continuous improvement with the factor loading of 0.91 and cultural preparation with a factor loading of 0.82, respectively. Although it may seem quite difficult at first glance, providing

cultural contexts can facilitate the engagement of employees in continuous improvement plans.

➤ The most important sub-dimensions in the dimension of Improvement with the factor load of 0.77 were the Competency-based succession planning with the factor loading of 0.92, Job rotation with a factor



### Lean human resources management

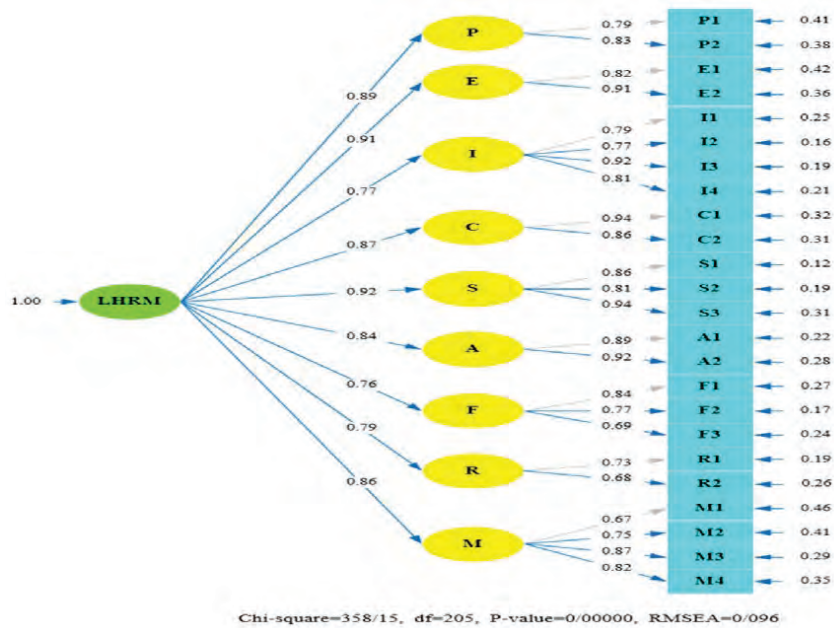


Fig. 3: The standard estimation model of "LHRM in the Islamic City Council of Tehran"

loading of 0.81, Enhancing productivity with a factor loading of 0.79, and Staff training with a factor loading of 0.77, respectively. The merit system prepares the ground for personal development, and helps individuals attain higher levels of insight, awareness, and capability.

➤ The most crucial sub-dimensions in the dimension of Remuneration with the factor load of 0.87 were the Giving suitable rewards with the factor loading of 0.94 and Creativity and innovation with a factor loading of 0.86, respectively. Creating a sense of satisfaction in employees will encourage them to repeat correct behaviors and wise actions.

➤ The most pivotal sub-dimensions in the dimension "Supply (S)" (with a factor loading of 0.92) were "Competency-based selection (S3)" (with a factor loading of 0.94), "Attracting multi-skilled employees (S1)" (with a factor loading of 0.86), and "Meritocracy (S2)" (with a factor loading of 0.81), respectively. Targeted selection of qualified personnel is a key factor that can substantially influence an organization's performance, capacity, and productivity.

➤ The most central sub-dimensions in the dimension "Compensation System (Benefits and Rewards) (A)" (with a factor loading of 0.84) were "Payment system based on performance (A2)" (with a factor loading of 0.92) and "Providing welfare and

medical services to staff (A1)" (with a factor loading of 0.89), respectively. The performance-based payment model aims to reward the measured dimensions of performance and uses financial incentives to encourage employees to achieve their predetermined goals.

➤ The most key sub-dimensions in the dimension "Flow" (with a factor loading of 0.76) were "Staff empowerment (F1)" (with a factor loading of 0.84), "Developing the scope of staff responsibility (F2)" (with a factor loading of 0.77), and "Socialization process (F3)" (with a factor loading of 0.69), respectively. Today, human resources (HR) are considered the most valuable factors of production, the most important capital, and the main sources of competitive advantage and basic capabilities in organizations; therefore, employee empowerment is among the most effective strategies used to achieve competitive advantage.

➤ The most vital sub-dimensions in the dimension "Relationships (R)" (with a factor loading of 0.79) were "Developing relationships on the basis of mutual trust and commitment (R1)" (with a factor loading of 0.73) and "Group coordination and decision-making (R2)" (with a factor loading of 0.68), respectively. Promoting organizational efficiency requires coordinating effective and genuine efforts of

employees who work in a safe work environment.

➤ The most requisite sub-dimensions in the dimension “Maintenance (M)” (with a factor loading of 0.86) were “Appropriate job promotion path (M3)” (with a factor loading of 0.87), “Aligning the objectives of individuals and organizations (M4)” (with a factor loading of 0.82), “Workplace conditions (M2)” (with a factor loading of 0.75), and “Low-level management (M1)” (with a factor loading of 0.67), respectively. Identifying the right career path for staff contributes to the retention of skilled workforce.

## DISCUSSION

From the perspective of the model and its components, there are some differences between this study and other similar investigations concerning the presentation of a LHRM model; e.g., one can argue that the dimension “training and multi-skilled employees” is consistent with the sub-dimensions associated with the dimension “improvement” compared to the model offered by [Kosonen and Buhanist \(1995\)](#). Furthermore, there were no dimensions relating to “Performance Appraisal”, “Employment”, “Remuneration”, “Supply”, “Compensation System (Benefits and Rewards)”, “Flow”, “Relationships”, and “Maintenance”, which were achieved in the model, in the above-listed model. Relative to [Nightingale's \(2002\)](#) model, one can say that the dimension “identifying and optimizing the flow of the organization” and “assurance of the integrated flow of information” are in line with the sub-dimensions related to the “flow” dimension. The dimension “optimization of capabilities and the optimal utilization of individuals” are in agreement with the sub-dimensions associated with dimension “optimization”. Besides, other dimensions related to the model gained are absent in the above-mentioned model. In comparison with the model presented by [Joyce and Schechter \(2004\)](#), the dimension “Formulation of excellence programs” and “training and employment of qualified experts” overlap with the dimension “improvement”, but it does not have an overlap with other dimensions. Compared to the model provided by [Johnson et al. \(2012\)](#), the dimensions “development of an annual intelligent system” and “problem solving, training, transfer and knowledge” overlap with the dimension “improvement” but have no overlap with other dimensions. Relative to the model proposed by [Tekez and Taşdeviren \(2016\)](#), the dimension “performance management” overlaps with

the dimension “performance appraisal”, but it does not have overlap with other dimensions at all.

## CONCLUSION

One of the most important reasons for the success of organizations is choosing a new method of human resource management called LHRM. LHRM is an approach to increase productivity and efficiency and minimize costs and losses. This study aimed to evaluate a LHRM model in the Islamic City Council of Tehran. The relationships between the components of the developed model were explored based on a quantitative study performed in Tehran's City Council. After factor analysis of each of the dimensions of the “LHRM management model in the Islamic City Council of Tehran”, the measurement model of any of the model dimensions, i.e. “Performance Appraisal”, “Employment”, “Improvement”, “Remuneration”, “Supply”, “Compensation System (Benefits and Rewards)”, “Flow”, “Relationships”, and “Maintenance”, was explained. Moreover, the relationships between observed and latent variables in Tehran's City Council were approved, and the fit indices were evaluated to be at a desirable level. The following items are suggested to upgrade the circumstance of LHRM in Tehran's City Council in accordance with the results of the standard estimation model:

The most essential sub-dimensions in the dimension of “Performance Appraisal (P)” are “Innovative performance appraisal systems (P2)”. It is recommended to the managers of Tehran's City Council that they can cause an enhancement in the productivity and performance of the organization and transfer the implementation of the principles and techniques of the lean approach in other sectors of the organization to the fullest extent with a concentration on cost management and staff activities and assessment of their performance. The most critical sub-dimensions in the dimension of “Employment (E)” are “Staff involvement in continuous improvement (E2)”. The engagement of employees in their conscious and clever affairs and attempts accompanied by work discipline can influence the amount of productivity and continuous improvement, particularly in an agitated setting with insecurity. The most important sub-dimensions in the dimension of “Improvement (I)” are “Competency-based succession planning (I3)”. Managers are proposed to attempt the design of significant and arranged competency-based succession

planning programs for estimating and meeting the organization's future needs. Personal and professional fostering are combined with the strategy via a systematic process of competency-based succession planning, ensuring that the organization is ready to fill any key vacancy jobs with the proper people at the right time. The most crucial sub-dimensions in the dimension of "Remuneration (C)" are "Giving suitable rewards (C1)". In this respect, managers are recommended to be assured that their workforces are aware of what they should do to receive rewards. The most pivotal sub-dimensions in the dimension of "Supply (S)" are "Competency-based selection (S3)". It is advised to the managers to take into consideration both the criteria of expertise and commitment in the selection of persons. The most central sub-dimensions in the dimension of "Compensation System (Benefits and Rewards) (A)" are "Payment system based on performance (A2)". Since performance appraisal attempts to search the best, most perfect, least expensive, and most effective means of the correlation between measuring job performance and job satisfaction and is regarded as a critical approach to upgrade the performance of an organization, it is suggested to the managers to methodically devise their payment system on the basis of staff performance. The most key sub-dimensions in the dimension of "Flow" are "Staff empowerment (F1)". Empowering employees is among the strategies, which could lead to an enhancement in organizational productivity and eventually promote the organization's manpower in each small and large department substantially so that a LHRM is implemented. It is recommended to the managers to purposefully follow the empowerment of HR. The most vital sub-dimensions in the dimension of "Relationships (R)" are "Developing relationships on the basis of mutual trust and commitment (R1)". Mutual trust gives permission to the interactions within the organization to flow extensively and steadily, which results in the organization's development. The most requisite sub-dimensions in the dimension of "Maintenance (M)" are "Appropriate job promotion path (M3)". Career path management is a means for the execution of human resource development (HRD) plans. The major objective of career path management is the generation of a balance between the needs of the individual and the organization so that it can provide situations by offering an obvious prospect until individual and organizational development be continuously carried

out. In general, it is recommended based on this research that to achieve LHRM in Tehran's City Council, the possibility of job relocation for employees is provided to train capable and multi-skilled employees. Also, identify the educational needs of individuals for holding targeted trainings. Due to preventing the loss of knowledge and experience of employees, it is recommended to use the knowledge management system. Finally, it is suggested that by appropriate performance evaluation and providing feedback to the staff, give them motivations to achieve high productivity. This study developed a comprehensive model for measuring LHR management in the Islamic Council of Tehran. Besides extending the existing knowledge about LHR management, the findings can also help members of the Islamic Council of Tehran make better decisions in future. The most critical limitation of the research is that the developments of Tehran's City Council have taken place so swiftly, and it is possible that the minds of the managers engaging in the interviews are on the basis of the matters shaped in the past and not encompass the current and future topics. Hence, the scholars are proposed to address a longitudinal survey of the research model to decline the impact of the prompt developments in the Islamic City Council of Tehran. The data in this approach are gathered over time until the relationship between variables is assessed over time.

#### AUTHOR CONTRIBUTIONS

D. halvachizadeh performed the literature review, questionnaire design, analyzed and interpreted the data, prepared the manuscript text, and manuscript edition. Gh. Memarzadeh and N. Mohammadi and H. Doroudi supervised and performed the corrections and reviewed the article and controlled the results of the research

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#### CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification,

double publication and, or submission, and redundancy have been completely witnessed by the authors.

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#### ABBREVIATIONS (NOMENCLATURE)

<i>AGFI</i>	Adjusted Goodness of Fit Index
<i>CFA</i>	Confirmatory Factor Analysis
<i>GFI</i>	Goodness-of-fit index
<i>HRM</i>	Human Resource Management
<i>KS</i>	Kolmogorov-Smirnov
<i>LHRM</i>	Lean Human Resources Management
<i>n</i>	Sample size
<i>N</i>	Size of the statistical population
<i>RMSEA</i>	Root Mean Square Error of Approximation
<i>Sig</i>	Significant number value
<i>TA</i>	Thematic Analysis
<i>TPS</i>	Toyota Production System
<i>Z</i>	Normal variable of the unit corresponding to 95% confidence level ( $Z_{\alpha/2} = 1.96$ )
$\delta$	Standard deviation of variable attribute ratio
$\varepsilon$	Standard error value = 0.05

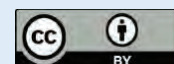
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ORIGINAL RESEARCH PAPER

## The physico-chemical assessment of urban river basin using macroinvertebrate indices for the environmental monitoring of urban streams

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### ABSTRACT

**BACKGROUND AND OBJECTIVES:** The major sources of pollution along the Mukuvisi River are industrial effluents from Msasa, Graniteside, and Southerton industrial sites, sewage effluent from Firls sewage works, pesticide and fertilizer runoff from Pension and surrounding farms, and domestic and diffuse pollution from residential areas. The primary objective of this study was to assess the impact of point and non-point pollution sources on macroinvertebrates variability and investigate the seasonal water quality deterioration along the Mukuvisi River. To evaluate macroinvertebrate community diversity using South African Scoring System 5 protocol for rapid bioassessment of water quality. The combined application of benthic macroinvertebrates and physico-chemical parameters was the focus of this research to validate the water quality status of the urban River systems concerning emerging pollutants in urban areas.

**METHODS:** According to the Harare municipality pollution control strategy and surveillance, only twelve accessible sampling points were chosen along the river. Macroinvertebrate samples and physico-chemical measurements were collected once or twice a month, according to the city of Harare's sampling schedule. The ancillary information, temperature, pH, and conductivity were measured on-site with a mercury bulb thermometer, a pH meter, and a conductivity meter, respectively. The standard South African Scoring System 5 sampling protocol was used for the sampling and identification of the macroinvertebrates community.

**FINDINGS:** The early assessments showed that water pollution was, in the 1st place and as a primary issue, a biological matter, and its primary effects could have been traced to living organisms. Eutrophication in Manyame catchment, Harare, Zimbabwe is subjected to prolonged and cumulative ecosystem stress because of human activities, sewage disposal, and industrial discharges, among other pollution sources. The Phosphorus-P, Biological Oxygen Demand, Chemical Oxygen Demand, and Ammonia-NH<sub>3</sub> (from 0, 6.9, 118, and 0 to 3.8, 81.9, 840, and 31 mg/L respectively) concentration increases downstream in both seasons. The Dissolved Oxygen saturation was 75% and 67% upstream in the dry-and-wet season and was reduced to 0% downstream in both seasons. The evaluation of macroinvertebrate diversity provided evidence that Mukuvisi River water was polluted based on the South African Scoring System, especially in the dry season.

**CONCLUSION:** The physico-chemical parameters were significantly related to macroinvertebrate diversity. In the assessment of river water quality, both macroinvertebrate indices and physico-chemical parameters can be sampled together to avoid bias. The results indicated that human activities from the upstream were inducing water pollution. Industries need to adhere to the wastewater discharge guidelines.

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## INTRODUCTION

Water is unquestionably the most valuable natural resource and the demand for this water is already exceeding the supply in many parts of the world, and as the world population continues to rise, so too makes the water demand. When it is unfit for its intended use, water is considered polluted (El Sayed *et al.*, 2020). Exaggerated irrigated agriculture, large scale-mining, power generation, heavy industries, and inadequate domestic sewage treatment have seen rivers turn into pollution drains (Golfieri *et al.*, 2018; Phiri, 2000). In Africa, some water reservoirs are experiencing somewhat different forms of environmental impact, the like as Lakes Victoria, Tanganyika, and Malawi (Nemery *et al.*, 2018; Alin *et al.*, 1999). Global statistics indicate that more than two-thirds of the urban population is below the poverty line (Tacoli *et al.*, 2015; Duque *et al.*, 2015; Chant and Datu, 2015). Seventy percent of cities' inhabitants live in slums (Wu *et al.*, 2013; Chen *et al.*, 2013; Bhattacharya *et al.*, 2012), with insufficient water and sanitation setups, poor health environments, and a lack of social cohesion or individual rights. The growth and development of urban areas are affecting the water quality, leading to the eutrophication of several water bodies (Kibena *et al.*, 2014; Palamuleni *et al.*, 2011). Consequently, Zimbabwe is not an exception, the city of Harare is facing heavy pollution with the high growth of invasive plants in several water bodies including rivers and lakes (Dube *et al.*, 2018). Lake Manyame and Chivero are amongst the polluted water bodies with high eutrophication status (Shekede 2008; Chawira 2013). The source of contamination originates from the disposal of industrial and domestic wastes, as well as agricultural runoff (Dube *et al.*, 2018). The major sources of pollution along the Mukuvisi River are industrial effluent from Msasa, Graniteside, and Southerton industrial sites, sewage effluent from Firle sewage works, pesticide, and fertilizer runoff from Pension and surrounding farms, and domestic and diffuse pollution from residential areas. Different materials are being discharged into the receiving waters such as still wastes, fertilizers, and heavy metals from industrial sites as well as nutrients from wastewater treatment systems (Muserere *et al.*, 2014; Masere *et al.*, 2012). Other researchers concluded that high population growth and agricultural and industrial contaminations contributed to the pollution

of Manyame River being in the same catchment under study. Additionally, turbidity, nitrates, phosphates, and Dissolved Oxygen (DO) were greater than the Zimbabwe National Water Authority (ZINWA) maximum allowable concentrations (Masere *et al.*, 2012). The primary objective of this study was to assess the impact of point and non-point pollution sources on macroinvertebrates variability and investigate the water quality deterioration along the Mukuvisi River. In other ways, as water is a resource that requires to be conserved, monitored, and restored, one of the most effective ways to establish river basin health is through the benthic macroinvertebrates assessment as biological indicators. This is due to their ease of collection for quick valuations and their sensitivity to a range of stress including sewage pollution (Khatri *et al.*, 2021). Among other biological variables, benthic macroinvertebrates are the most used all over the world. To quantify biological status in rivers, biotic indices are applied as numerical expressions combining quantitative measures of species diversity with qualitative information on the ecological sensitivity of individual species (Medupin, 2020). To evaluate macroinvertebrate community diversity using South African Scoring System 5 protocol (SASS 5) for rapid bioassessment of water quality (Dickens and Graham, 2002; The Water Wheel, 2018) and its relationship to the physic-chemical parameters. The availability or absence of certain species determines the water quality of the sampling site because different species have considerably different pollution tolerances. This research study aims to offer how the macroinvertebrate taxa occurrences will be analyzed in different pollution levels and identify some specific taxa that potentially indicate certain levels of pollution along the Mukuvisi River. Our findings will provide information pharmacy to ecologists, water managers, stakeholders, and policymakers when decisions are to be made on upcoming studies on different rivers, lakes, dams, and streams to combat water contamination for monitoring exercises. The similarity index was used to categorize the comparison between the selected sample sites and the diversity of that area along the river. The combined application of benthic macroinvertebrates and physic-chemical parameters was the focus of this research to validate the water quality status of the urban River systems concerning emerging pollutants in the city. Additionally, the natural and anthropogenic

trends were to be determined to provide the current River status for future management and monitoring of pollution from the surrounding industries. . Additionally, the natural and anthropogenic trends were to be determined to provide the current River status for future management and monitoring or pollution from surrounding industries. To achieve the objectives of this study, the research was conducted in the capital city of Zimbabwe, Harare, from 2018 to 2019.

## MATERIALS AND METHODS

### Study area

The Mukuvisi River originates close to the City of Harare just below the Cleveland dam, rises to the east of the city, and drains into Lake Chivero. The Upper Manyame Sub-catchment (UMSC), the catchment (Fig. 1b) in which the capital city Harare lies, experienced significant population growth from 2 million in 2010 (Chirenda *et al.*, 2020) to over 2.7 million in 2012 (ZIMSTAT, 2012). Given an average annual growth rate of 2% for Harare (ZIMSTAT, 2012),

its population was estimated at 2.92 million in 2016. During the wet season, the mean annual rainfall is approximately 820mm, with a range of 440-1200mm, characterized by high intensities falling between November and March (Chirenda *et al.*, 2020), unlike during the cool and warm dry season, May to October.

### Physic-chemical data collection and measurement

Twelve accessible sampling points were chosen along the river, following the Harare Municipality surveillance and protocol of streams water quality monitoring strategy as shown in Fig. 1a. Macroinvertebrate samples and physic-chemical measurements were collected once or twice a month, according to the city of Harare's sampling schedule, from each site. Water samples were collected from each site and transferred to the laboratory and stored in a refrigerator for later analysis. Ancillary data was measured on-site to avoid deterioration of the sample. The ancillary information, temperature, pH, and conductivity were measured on-site with a mercury bulb thermometer, a pH meter, and a

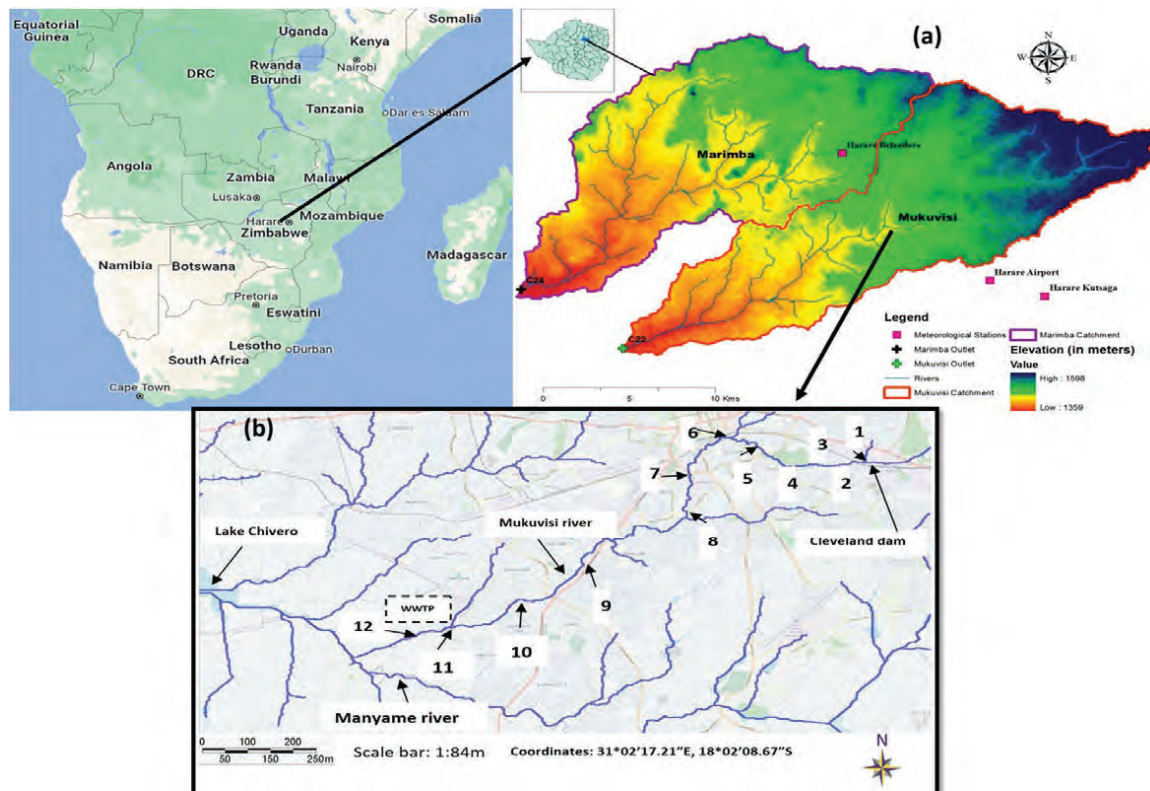


Fig. 1: 1a, a detailed aerial view of Mukuvisi River showing the sampling sites; 1b, show DEM for Mukuvisi River catchment (Google, 2022; Gumindoga *et al.*, 2014).

conductivity meter, respectively. In addition, DO was also fixed on-site in 300 ml bottles using Manganous Sulphate and alkaline iodide solution as the reagents. The Biochemical Oxygen Demand (BOD) was fixed and determined using the dilution method (Dube *et al.*, 2018) in the laboratory. Nitrates, ammonia, and phosphate concentrations were determined by titration. The concentrations of suspended solids were determined by filtering a 200 ml sample of water and evaporating it slowly in an oven at approximately 103–105°C on a pre-weighed filter paper. Turbidity and color were also determined using a turbidity meter and a comparator, respectively. The collected water samples were stored in 1-liter dark glass bottles, and immediately stored in a Cooler box (Therapak; Coleman, OR, USA) and transported to the laboratory as soon as possible. In the laboratory, samples were stored at 4°C until laboratory analysis within 24 h after sampling as suggested by World Health Organization. The water chemistry was measured through a DR3500 Hach Lange lab spectrophotometer (HACH Company, Loveland, CO, USA) and Hach Lange kits to measure, nitrate-nitrogen, orthophosphate, Chemical Oxygen Demand (COD), nitrate-nitrogen, and ammonium-nitrogen. In addition to this, independent analysis and external quality control were carried out by Harare water and ZINWA, as accredited laboratories.

*The sampling and identifications of macroinvertebrates* (Kebede *et al.*, 2020; Gumindoga *et al.*, 2014) elucidated that the surface current velocity at each site was determined by measuring the movement of a float over at least five meters. At first, a float was thrown into the flowing river water and a stopwatch was used to measure the time spent along the river for five meters this can give the flow velocity. This helps to understand the condition of each site and the organisms that can be found under different flow velocities as well as levels of contamination according to ZINWA among other pollution levels.

The standard SASS 5 sampling protocol was used (AQUASTAT, 2003). For the sampling and identification of the macroinvertebrate community, organisms were identified at the family level with the aid of macroinvertebrate identification field manuals (Molineri *et al.*, 2020; Wan *et al.*, 2018). Taxon number SASS 5 score and Average Score Per Taxa (ASPT) were calculated as stipulated in the SASS 5 manual (AQUASTAT, 2003). Samples were identified on-site as stipulated by SASS

5 protocol and only those that could not be identified on-site were taken to the laboratory for identification after preservation in 70% alcohol as suggested by Wan *et al.*, (2018). Moreover, the total impact of human activities was determined and corresponded on a scale between 0 to 10. The selected sampling sites were again classified into three different groups (low, mid, and high) of human activity impact derived from these established scores. So, the Scores were varying from 0 to 2 for severe impact sites; 2 to 5 for reasonable or mid-level impact, and >7 for safe site conditions. A kick sampling net was used to collect the macroinvertebrates with a square hand net with a mesh size of 0.5 mm and the measurements were conducted within 5 mins on each site. For each site, 3 collection replicates were conducted, each time, the collected sample was washed and rinsed to remove other microhabitats (macrophytes, sand, mud, and stones) and later conserved in a 95% ethanol. All the macroinvertebrates were identified at family levels with a stereo Olympus SZX10 (LED-light) microscope (Olympus, Tokyo, Japan).

#### *Analytical framework*

A hierarchical method, the average linkage cluster analysis, was applied to the mean values of the invertebrates for each site (Kebede *et al.*, 2020; Karrouch *et al.*, 2017). Hierarchical classification groups similar sites together, indicating relationships among these groups along a stream (Golfieri *et al.*, 2020; Cohen *et al.*, 2006). Thus, the number of different taxa in each sample was determined, counts from samples of each site were pooled and the relative percent abundance of each taxon was calculated. As suggested by Karrouch *et al.* (2017); Chant and Datu, (2015) the South African Scoring System Version 5 protocol, a rapid method for water quality assessment developed along the lines of the British Biological Monitoring Working Party 7 (Palamuleni *et al.*, 2011; Phiri 2000), was applied to the macroinvertebrate samples. An Average Score Per Taxon (ASPT), the mean rating for all the families in the sample, was calculated (Nemery and Nkulu 2020; JICA, 1996). The condition of each site was then determined using the SASS score, No. of taxa and the ASPT (Ruiz-Picos *et al.*, 2017).

*GenStat 10.3 DE Regression analysis for data analysis*  
The GenStat (Vers. 21.1 DE) was used to run a



regression model to show the relationships between macroinvertebrates diversity and physico-chemical variables along the Mukuvisi River. The physico-chemical parameters were regressed against the ASPT for dry and wet seasons. The coefficient of determination ( $R^2$ ) was established with the trend line fitted. Figures, graphs, and statistical analysis were produced by R-Software (vers. 4.1.2.).

## RESULTS AND DISCUSSION

### Water physico-chemical trend analysis

The water physico-chemical characteristics of each site are shown in Tables 1 and 2. The pH was generally basic in all sites along the stream for both seasons except site 3, which had acidic conditions in both seasons and is not within the acceptable limits of pH 6.0-9.0 according to the Zimbabwe National Water Authority (ZINWA) standards. In the dry season, sites downstream had acidic conditions of pH<6.0, probably influenced by industries through which this river passes. In both seasons, the ranges of temperature values were within the acceptable limits in most sites, as shown in Tables 1 and 2 except

for sites 10, 11, and 12 in the dry season, which had higher values. Electric Conductivity (EC) concentration was in the permissible range in most sites in the dry season.

However, sites 3, 10, 11 and 12 values were greater than the maximum acceptable concentration for Zimbabwean raw water, which is <1000 dS/cm. The EC concentration was above the normal standards in most sites in the wet season, as shown in Table 2, and this mostly decreases as we approach the lower sites. This could be due to intermittent increases in daily temperatures during the rainy season or otherwise the rising of underground water levels having an impact on the impoundment. Therefore, the dilution effect from rainfall tends to reduce the concentrations of nutrients hence the downstream sites be disposed to have lower EC than in sites above as well during the dry season.

Levels of turbidity and suspended solids (SS) fluctuated greatly above the acceptable limits in all seasons. However, sites 3 and 12 had values above the normal standards. The discharge of chemical effluent might induce this from the Zimphos industry

Table 1: Averages of physicochemical water variables at sites on the Mukuvisi River during the dry season

SITE	PH	EC	TEMP	DO	NO <sub>3</sub>	NH <sub>3</sub>	PO <sub>4</sub>	COD
1	6.075	450.5	19.875	4.2	0.01	0.6	0.2	213
2	5.945	630.5	22.75	3.4	0.1	0.6	0.2	358.225
3	2.9925	3023.75	24.25	2.6	0.08	0.5	2.4	998.2
4	6.0875	670.75	20.625	4.8	0.26	0.78	1	358.35
5	7.605	520.5	20	4.8	0.4	0.8	0.2	456.175
6	6.0675	636.5	24.5	3.9	0.2475	0.79	0.2	653.05
7	6.9	570.75	24.25	5.2	0.175	0.6	0.1525	356.375
8	6.145	611.25	23.875	3.7	0.01	0.6	0.53	405
9	4.89	1450.5	23.625	4.5	0.1	0.61	1.2	714.1
10	4.98	1590.25	26	0.7	0.02	0.5	2.6675	906.675
11	5.89	1490.75	25	1.6	0.16	0.62	1.2	539.675
12	4.89	2100.9	28.375	0	0.025	0.5	3.12	2227.325

Table 2: Averages of Physico-chemical water variables at sites on the Mukuvisi River during the wet season

SITE	PH	EC	Temperature	DO	NO <sub>3</sub>	NH <sub>3</sub>	PO <sub>4</sub>	COD
1	5.6	3500.6	20.675	5.95	0	0	0	117.75
2	6.68	1560.01	22	2.8	0.1	9.5	0	290.895
3	4.2	4120.55	21.5225	5.1775	0.19	9.505	0.6225	598.48
4	4.25	3100.5	22.1	4.675	0.1025	8.23	0.06	310.4125
5	6.3	1250.11	21.85	4	0.7	9.3925	0.015	322.025
6	6.4	1350.99	21.75	4.1975	0.135	4.5	0	267.89
7	6.125	1500.6	22.75	3.85	0.14	4.7	0	270.1025
8	6.7	1450.02	21.75	5.45	0.1	8.5	38.225	299.835
10	7.0875	500.56	22.6	3.225	0.0675	18.94	0	490.735
11	6.975	976.25	22.35	0.725	0.07	16.95	0.5225	458.55
12	8.325	1005	25.87	0	0.05	31.115	3.81	840.415



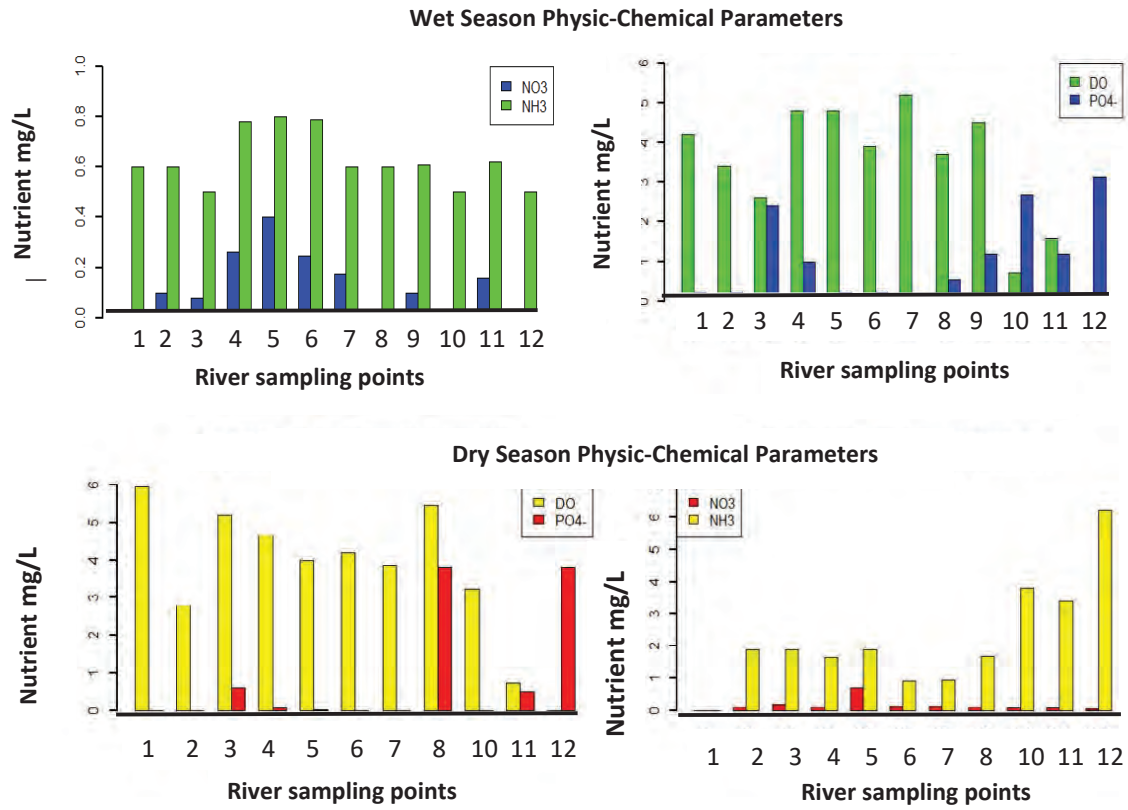


Fig 2: Seasonal variations in water quality along Mukuvisi River, 2018-2019

Table 3: The results show DO percentage saturation in dry and wet seasons

	SITE	1	2	3	4	5	6	7	8	9	10	11	12
DO %	Dry	75	52	94	61	59	48	100	68	66	9	7	0
SATURATION	Wet	67	19	59	54	46	48	40	63	ns*	36	1	0

Key= ns\*-no sample

and the Firle sewage treatment works. In the dry season, ammonia was slightly above the normal standards of raw water, which is < 0.5 mg/l, in some sites and increased downstream as shown in Fig. 2. Few sites had these high values of ammonia in the wet season with concentrations above normal limits and also increased towards site 12. P concentrations were generally lower than normal standards, that is <0.5 mg/l, though they increased towards site 12 in both seasons. On-site 8 phosphates were above the acceptable levels in both seasons. Nitrate was very low, in all seasons, and was within the sensitive and normal standards of the raw water of Zimbabwe, that is <3 mg/l. Almost no nutrient was found on site 1 during the rainy season with the possibility of

the dilution effect and limited access to agricultural discharges or runoff. The COD was determined and found to be very high above expected values of <30mg/l in all seasons. The COD levels continued to increase downstream, as in Fig. 2. The DO % saturation was found in the normal acceptable range in most sites along the river as shown in Table 3, and as indicated in the ZINWA guidelines. Generally, the DO levels decrease downstream up to nil in site 12 in both seasons.

#### Macroinvertebrate community

Three groups of sites showed similarity in the macroinvertebrate diversity obtained. Sites 5, 6, and 1 showed that the water quality was excellent,

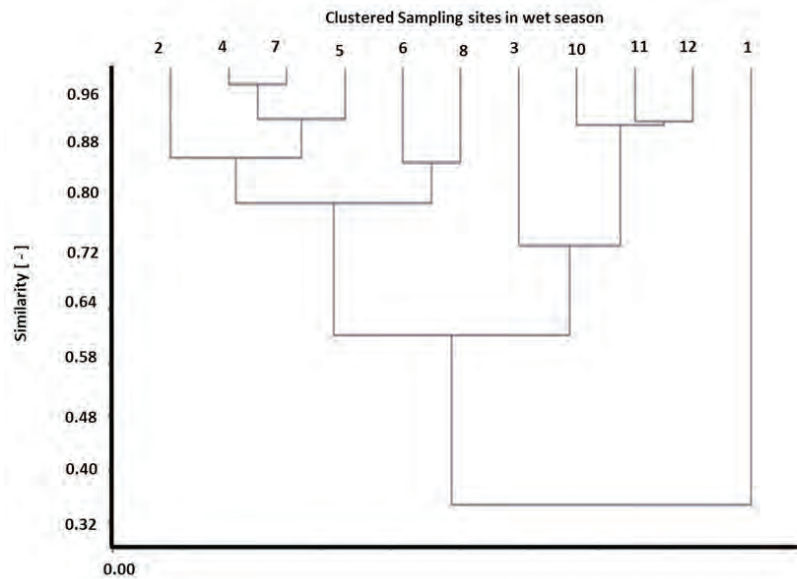


Fig 3: Cluster Dendrogram of 11 sampling sites based on the average linkage cluster analysis of macroinvertebrates in the wet season.

especially site 1, which is at the mouth of the Cleveland dam, as shown in Fig. 1. The other groups were composed of sites 3, 10, and 12. The last group consists of sites 2, 4, 7, 8, 9, and 11 show a minimum pollution percentage likeness to other sites considering the macroinvertebrate diversity. Generally, the three groups show that the percentage similarity of the first group to others is lower, by 40%, and the other two are almost above 60%. This deviation can be due to the limited availability of water in the dry season, so the self-purification of wetlands (Patang *et al.*, 2018) found along the river channel, might be very high since the wetlands were able to purify minimum available water in other sites.

#### Wet and Dry season

A dendrogram is a tree structure used to visualize the results from hierarchical clustering (Arief *et al.*, 2017) and it was used to gather site similarity or linkage clustering in both dry and wet seasons. Three groups were established in the wet season, using a cluster dendrogram software, where site 1 stood on its own being different from other sites with a percentage similarity of less than 5%. This simply means that site 1 is not significantly polluted, as indicated in Fig. 3.

Site 9 was not sampled because of inaccessibility due to the bridge under construction along Beatrice

Road. Generally, there were more macroinvertebrate families obtained in the wet season than in dry Fig. 4, apart from sites 1, 5, 6, and 8 which had numbers comparable to those in the wet season. In the dry season, sites 1, 5, and 6 seem to share similar characteristics of better quality over others as indicated in Fig. 4.

#### The Mukuvisi River quality status based on the SASS 5

A summary of SASS Scores, number of taxa, and ASPT is shown in Table 4. Site 1 in the dry season had the highest SASS score and the number of taxa hence shows good conditions as indicated in Table 5 and site 5 had the highest ASPT. In the dry season, Site 3 has the lowest SASS score, No. of taxa and the ASPT meaning poor conditions of water quality however, site 12 indicated the same ASPT for both seasons.

#### Macroinvertebrate and physico-chemical relationships

The invertebrate sample scores and the ASPT were significantly correlated to the water conductivity and DO as well as pH, temperature, ammonia, nitrate, COD, and phosphates.

Selected sites along the Mukuvisi River greatly differed concerning the selected physico-chemical variables. Generally, the water quality decreased along the course of the Mukuvisi River mostly in the dry season but did not change much in the wet

# *Biomonitoring of urban streams using benthic macroinvertebrates*

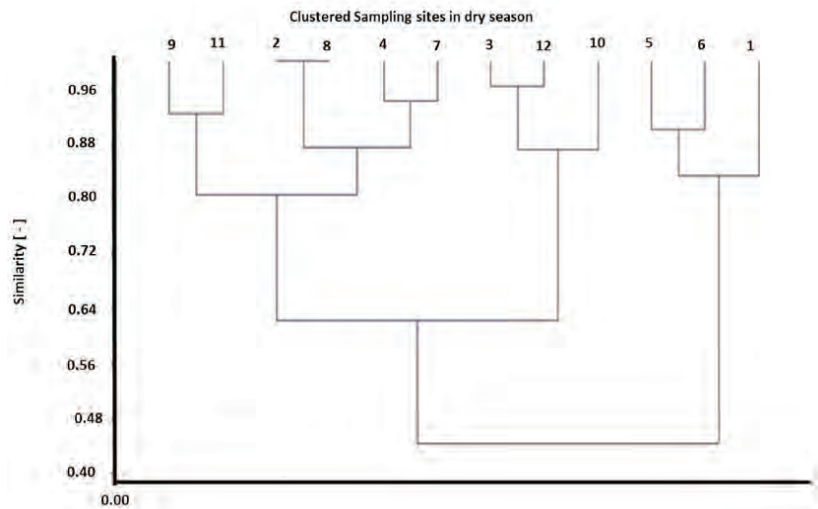


Fig 4: Cluster Dendrogram of 12 sampling sites, based on the average linkage cluster analysis of macroinvertebrates in the dry season

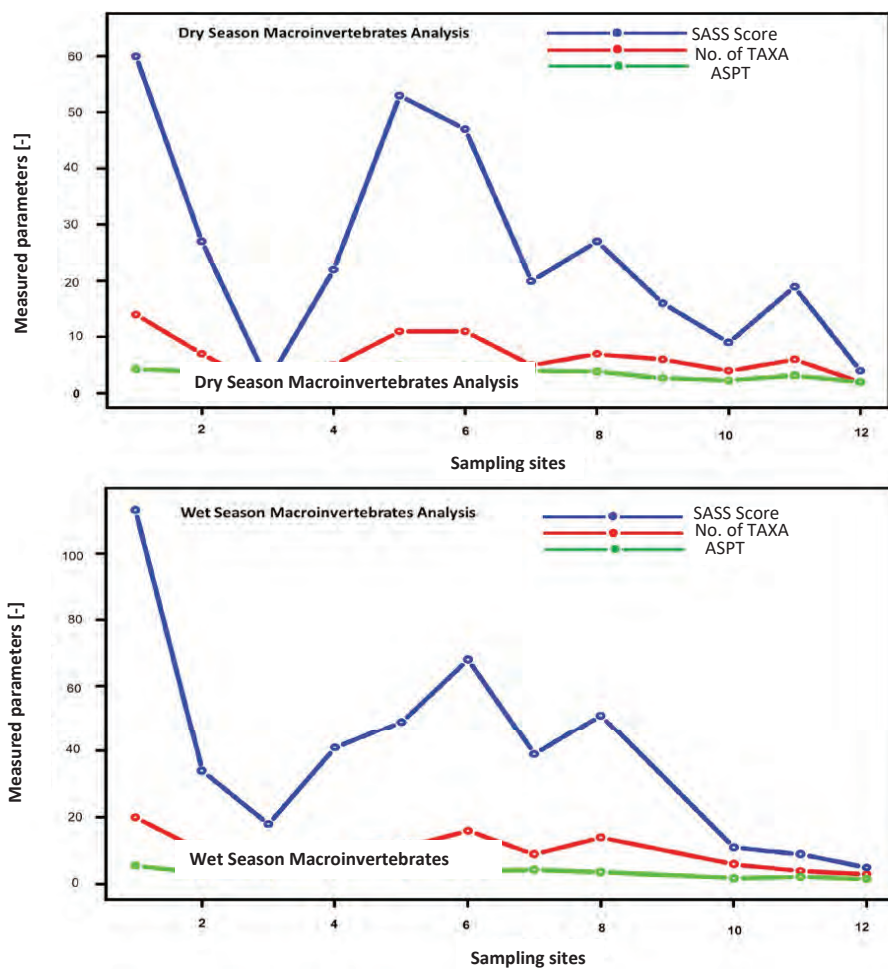


Fig 5: Results of macroinvertebrate scores, number of Taxa, and the average score per taxon (ASPT) in dry and wet seasons on the Mukuvisi River based on SASS 5.

Table 4: The scores used to determine the condition of a site using SASS 5 (Ollis *et al.*, 2006)

Condition	Habitat score	Sample score	ASPT
Excellent	>100	>140	7
Good	80–100	100–140	5–7
Fair	60–80	60–100	3–5
Poor	40–60	30–40	2–3
Very poor	<40	<30	<2

Table 5: Results of macroinvertebrate scores, number of Taxa, and the Average Score Per Taxon (ASPT) in dry and wet seasons on the Mukuvisi River based on SASS 5.

Site	Site description	DRY SEASON			WET SEASON		
		SASS Score	No. of Taxa	ASPT	SASS Score	No. of Taxa	ASPT
1	Dam mouth	60	14	4.29	113	20	5.56
2	Mutare road bridge	27	7	3.86	34	10	3.4
3	Zimphos	2	1	2.00	18	4	4.5
4	Msasa railway cross	22	5	4.40	41	9	4.56
5	Chiremba road bridge	53	11	4.82	49	11	4.45
6	Seke road bridge	47	11	4.27	68	16	4.25
7	Cripps road bridge	20	5	4.00	39	9	4.33
8	Boshoff road bridge	27	7	3.86	51	14	3.64
9	Beatrice	16	6	2.67	NS*	NS*	NS*
10	Amalinda road bridge	9	4	2.25	11	6	1.83
11	Above Firle	19	6	3.17	9	4	2.25
12	Below Firle	4	2	2.00	5	3	1.67

\*NS-No sample, was inaccessible due to weather

season. The variances in the quality of water from the twelve sites reflect the differences in the activities conducted. Industrial sources, domestic and sewage effluent disposals, as well as anthropogenic activities, are the leading causes of a decrease in the water quality along the Mukuvisi River as revealed by Phiri (2000). The benthic community in lotic water is strongminded by the existing flow speed, the substrate, physic-chemical variables of the water, and the zoogeographical region (Jerves-Cobo *et al.*, 2020). Measurement by observing the changes in the number of taxa defines ecosystem degradation by pollution, which is a more responsive measure than other ecological measures such as the number of organisms (Akay and Dalkiran, 2020; Masere *et al.*, 2012). Mollusks are some of the least tolerant macroscopic invertebrates to heavy metal pollution and Chironomidae larvae usually dominate the macroinvertebrate communities of sites that are glossily polluted by heavy metals (Molineri *et al.*, 2020; Wan *et al.*, 2018). Subsequently, the relationship between the observed variables showed an increase in conductivity as water flow increased

signifying the effect of point source pollution, which is a robust connection between discharge and the Manyame catchment area advocates for the impact of urban runoff and other point source pollution. Such contributions could have led to the dominance of the Chironomidae larvae family. Moreover, the results from several sites exhibited that Baetidae, Tubificidae, and Chironomidae were plentiful during the dry season when the Mukuvisi River discharge was less, however, it could be found in less abundance during the end of summer when the river flow was maximum. The concentration of DO was at its peak during the wet season when the river discharge was high.

The high relative abundance of oligochaetes on sites 7, 8, 9, and 10 may be seen as evidence of organic pollution. A positive correlation ( $R^2=0.5873$  and  $R^2=0.6908$ ) was attained with the ASPT in dry and wet seasons, respectively, as in Fig. 5. The sources of the DO might be the atmosphere, tumbling water mix, rooted aquatic plants and algae and probably these increase its concentrations. However, the levels decrease downstream where there is much

sewage effluent with high COD levels, and few macroinvertebrates can survive. There was a weak positive correlation between nitrates and the ASPT with regression coefficients  $R^2=0.3747$  and  $R^2=0.0595$  in dry and wet seasons.

## CONCLUSION

The water quality trends deteriorated downstream due to heavy industrial activities and high domestic wastewater discharges into the Mukuvisi River, especially in the dry season. Higher concentrations of pollutants were found where there was a point source, a case of site 3 at Zimphos and site 12 just below Firlle sewage works. The evaluation of macroinvertebrate diversity provided evidence that the Mukuvisi River water is polluted based on the SASS 5 protocol, especially in the dry season. The physico-chemical parameters were significantly related to macroinvertebrate diversity. Conclusively, in the assessment of river water quality, both macroinvertebrate indices and physico-chemical parameters can be sampled together to avoid bias. The results indicated that human activities upstream are causing pollution in the river and proper controls on agriculture should be monitored to avoid injurious impacts. Industries need to adhere to the wastewater discharge guidelines and exercise caution when discharging unpleasant wastewater from the factories. The availability of oligochaetes downstream clearly exhibited organic pollution, and this implicates DO levels and affects aquatic species in the river system and reservoirs downstream. This bio-assessment technique is cheap and affordable, and it should be conducted so often to monitor the urban stream's health status. Therefore, it is concluded that the connection between the observed benthic macroinvertebrates along the Mukuvisi River and its physicochemical variables designates those geomorphologic differences co-vary with the river flow, its substrate, and the conductivity alongside the river sites which somehow impacted their fauna collection. The results also exhibit that domestic pollution is not a major challenge in the Mukuvisi River, apart from the higher concentration (mg/L) of  $\text{PO}_4^{3-}\text{P}$  but anthropogenic activities along the riverbanks. The results also can be a foundation for low-cost and ideal solutions to support administrative procedures in the Manyame catchment in the long term. As a future view, there is a need to monitor the diversity and trend

analysis of these macroinvertebrates using Bayesian statistical analysis to validate the data obtained and be able to predict the future estimations through model simulations. These endeavors might safeguard the conservation of water quality in Lake Chivero and the Manyame catchment at large. It is, therefore, recommended that (1) The City of Harare should improve its sewage reticulation system to cater to the increased population in Harare, (2) Industrial effluent should be monitored, and the City of Harare-Harare Water should control the treatment of the effluent prior to discharge into the environment, (3) EMA should enforce the policy of permits on industries by enforcing serious charges and ensuring that their pre-treatment plants are working properly.

## AUTHOR CONTRIBUTIONS

O. Gotore performed the literature review, and experimental design, analyzed and interpreted the data, and prepared the manuscript text, and manuscript edition. A. Munodawafa and T. Itayama conducted the supervision of this work and resources as well as the data check. R. Rameshprabu, T.P. Masere, and V. Mushayi helped in the literature review and manuscript preparation, English grammar and spelling check.

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## CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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#### ABBREVIATIONS (NOMENCLATURE)

ASPT	Average Score Per Taxa
EC	Electric Conductivity
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
SS	Suspended Solids
SASS	South African Scoring System protocol
UMSC	Upper Manyame Sub-catchment
ZINWA	Zimbabwe National Water Authority

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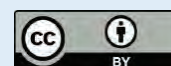
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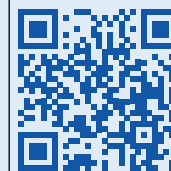


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ORIGINAL RESEARCH PAPER

Evaluation of the energy consumption mechanism of settlements in urban morphology context

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ABSTRACT

**BACKGROUND AND OBJECTIVES:** According to global statistics, the amount of energy consumption in recent decades has grown uncontrollably and maximally due to the energy consumption in urban fabrics, except for transportation, which is clearly the quality of placement and construction of building masses in the context of urban morphology is more important. The main purpose of this study was to evaluate the components of energy consumption in urban settlements based on the urban morphological model's sustainability.

**METHODS:** Research in terms of structure was analytical-descriptive, which in terms of the main purpose, was a type of applied and developmental research. The method of data collection was as documentation and using Bing Map data reference and data generation with Arc GIS software and 3D modeling with Google SketchUp software, the dimensions and indicators of which were extracted in the form of figure ground. Case study sample on a scale of 150 by 150 as an isolated urban fabric in the explained scales, different building configurations, the common types of which have been selected and simulated according to the form structure of Khorramshahr urban settlements. Energy considerations were also assessed using energy analysis software with an urban climate analytical approach such as Climate Consultant and Envi-Met.

**FINDINGS:** The results showed that assigning a ranking weight to each morphotype for each parameter, the average weight of each case, which includes all 5 parameters, indicates the rank position of morphotypes in Khorramshahr. From four types studied, High-rise buildings with an average of 3.13 worst impact and detached housing with an average of 1.93 have the best impact on the microclimate formed around them, which obviously energy efficiency according to climatic indicators and microclimate metrics can be emphasized the principle of optimal limit.

**CONCLUSION:** The findings of the current research showed the energy consumption status according to the evaluation of morphological variables. It was the morphotypes as well as the climatic parameters that have determined the specific results of each case and also provided the appropriate type and rating. In future research, by explaining the optimal model of urban fabric stability model based on the concept of sustainable morphology, each morphotypes in the optimal state can be evaluated.

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## INTRODUCTION

According to global statistics, global energy consumption has doubled every decade and is projected to increase by 54% by 2025, while in this report, the highest energy consumption is allocated to developing countries, including Iran, where the average annual energy consumption has grown by 10% (International Energy Agency, 2021a). With the acceleration of urbanization and population growth, cities are increasingly suffering from energy management crises, which is clearly more important in third world countries. Urban energy consumption is classified into 5 main sectors of industry, transportation, housing, services and agriculture. The maximum energy consumption in third world countries occurs in the transport and residential sectors, among which buildings are responsible for consuming the most (40%) of energy and greenhouse gas emissions (Wang et al., 2021; UNEP, 2015), and the greatest potential for reducing greenhouse gas emissions by about 29% by 2030 can be achieved in the case of buildings (Boccalatte et al., 2020). According to the United Nations, the shape of the city has a direct impact on energy consumption (Palme and Salvati, 2021). Thus, the shape of the city and its design pattern are influential in energy consumption through features such as building density, land use mixing, communication network pattern, and public transportation network (Ali-Toudert, 2017; Boccalatte et al., 2020; Chen et al., 2021; Hadavi and Pasdarshahri, 2021). In general, for a developing country, valuable information can be obtained by analyzing the urban structure on the subject of urban morphology (Öztürk et al., 2021). Specifically, in order to study the structure of urban settlements in the field of their sustainability, the issue of urban morphology as a context for the formation of urban context needs to be considered that the issue of energy in urban context is in the relationship between building and texture. This relationship is one of the most important conceptual challenges in morphological components, both in terms of density and orientation. The energy resource change plan is based on five axes, according to which the highest urban energy consumption takes place in buildings (Kamal Abidi, 2021). Based on their effects on climatic factors around and above them, including temperature, relative humidity, wind speed and direction, and sunlight, urban built elements create

an artificial climate that always interacts with each other (Naryapraği and Polat, 2020). For this reason, to optimize energy efficiency in the city, buildings will be the main focus. Among the consumed energies, solar radiant energy on the one hand and heat energy demand on the other hand are the most important issues in energy efficiency in the city. In fact, the energy consumption of buildings is due to the density and form of buildings and also their placement relative to each other, and by making changes in these cases, the amount of energy consumption by buildings in the urban context can be significantly reduced (Kolokotroni et al., 2012; Strømman-Andersen and Sattrup, 2011). In recent years, issues related to climate change and energy have become more important and focused in urban studies (Song et al., 2020). Today, cities are responsible for emitting more than 70% of Greenhouse Gases (The Greenhouse Gases Protocol, 2015), although cities cover 2% of the biosphere surface (Huizenga et al., 2001), their inhabitants consume 60 to 80% of the world's energy (Perera et al., 2021). As this issue intensifies, energy efficiency is a key factor in urban development (Jafarpur and Berardi, 2021; ESMAP, 2014). This leads governments to make concerted efforts to reduce greenhouse gas emissions (Fernandez-Luzuriaga et al., 2021). Urban design in the approach of sustainability, the concept of urban form is the most important intermediate concept that has different types, but clearly the compact city shape has a positive performance against climate issues (Bibri et al., 2020). The urban form is shaped in the direction of a product that has been obtained in the context of morphology and the study of its forming layers (Carmona, 2021). On a medium scale, and especially in urban micro-scale, in relation to buildings and the surrounding environment, each building changes the climate around it. These changes take place under the title of micro-urban climate and the impact of factors such as geometry and cross section of the city, shape, and height, size of buildings, the direction of streets and buildings and the level of open spaces (Yanxue Li et al., 2021). In the topic of micro-structure of urban climate, parameters of urban morphology can be proposed that examine and explain the relations with a morphological approach. Elements such as masses, passages and blocks as the main cases of urban morphology have indicators in which the meaning of this meaningful

relationship can be analyzed practically the most accurate effects (Jafarpur and Berardi, 2021). Measuring the density of the constructed environment as well as indicators such as building surface ratio, open space ratio and floors can also be considered as the main interveners of the research (Bagaei *et al.*, 2020). In general, the concept of energy and its application in the city requires behavioral structuring. Based on the dimensional division of energy, passive energies, which are mostly used in buildings, are practically in a short and unrelated path in research (Ding, 2020). While the existence of a hierarchical explanation and analysis of energy in the city requires the involvement of all three macro, middle and micro scales, which can be used to extract energy efficiency models and introduce optimal models based on future research, in addition the type of orientation of the passages and the mass itself is also very important in the behavior of the urban fabric as an urban settlement. According to previous studies, cases can be pointed to similar. Delmastro *et al.* (2016) in a study entitled "Selective method of applying energy policies for buildings on an urban scale", have addressed the issue of energy efficiency policies in urban contexts with a focus on the function of buildings in order to explain low carbon cities provides models and strategies for policy-making in the program structure and urban design. Another case parallel to the current research approach, entitled "Urban morphological indicators for solar energy analysis" by Morganti *et al.* (2017), which is different in the depth and type of analysis method and scale. Sadegi and Li (2019) in a study entitled "Analysis and innovation on high-efficiency building materials with an approach to energy performance and micro-urban climate in residential textures" began to explore a kind of micro-scale and examine the influential variables in micro-climate urban and the type of characteristics of various materials in the building. Finally, it has extracted its results from the prominent features of materials such as the level of surface reflection and the type of urban wall effect. Mirmoghtadaee *et al.* (2017) in a study with the title of "Measuring the effect of urban geometry on external thermal comfort conditions at the micro-scale of urban climate" pointed out that a kind of open space of a residential complex as the main type of daily urban fabric. This fabric showed as planned from the perspective of geometry effects. The study

explained that the micro-type of urban climate and morphological parameters have been analyzed in a relationship that finally emphasizes the quality of urban geometric design. Besides, the influence of factors such as sky view factor, proportions and orientations as the main variables. In a general view, according to the background, it can be pointed out that most of these researches have been done on analytical structure in the concept of a model and conceptual framework by introducing indicators and precise parameters practically taking into account all interfering parameters in most researches. The sustainable urban form, emphasized in these current studies, with the compactness of urban masses subject has not been practically examined and systematically analyzed. Therefore, according to the above, the main purpose of this study is to evaluate the components of energy consumption in urban settlements based on the model of urban morphological stability, which can be based on questions such as; By what criteria can the components of energy consumption examine the variables affecting the physical form of Khorramshahr city in the subject of energy consumption developments? And what are the effects of urban morphological parameters and its main variables on the focus of energy transformation in Khorramshahr urban settlements? This study aims to evaluate energy consumption mechanism of settlements in urban morphology context in the case of Khorramshahr city. The current study has been carried out in Kish/ Iran in 2021.

## MATERIALS AND METHODS

The research is descriptive-analytical in terms of structure and according to the main purpose, it is an applied and developmental research. The method of data collection is as documentation and using Bing Map data reference and data generation with Arc GIS software and 3D modeling with Google Sketch Up software. The issue of energy in urban settlements has been considered, the dimensions and indicators extracted from it in the form of figure ground maps in the explained scales and different building configuration, the common types of which are selected. In according to the formal structure of Khorramshahr urban settlements and the perspective of energy considerations will be evaluated using energy analysis software with an



analytical approach to urban climate such as Climate Consultant and Envi-Met. In the first step, in the city of Khorramshahr, a sample of urban areas selected at a scale of 150 by 150 as an isolated urban fabric and it will be presented in the form of a real sample types. The reason for choosing the morphotypes is also based on the following factors; Be in the center of transportation and close to the main urban accesses of Khorramshahr; Have a space organization appropriate to the principle, area, axis and node; To be present in adjacent areas due to the creation of overlapping and similar micro-climate; The selected types have substantial differences in structure as well as the type of porcelain mass. The morphology of the studied types based on research indices and typology in modern urban planning based on LSE (*London School of Economics*) sources include discrete morphotypes, compact block, high-rise building, slab housing and detached morphotype, which according to the explanation of the combined scenario the basis of the principle of stability has been calculated and performed. In the next step, the parameters affecting the energy consumption in the urban fabric as a basis in the city of Khorramshahr are included in the whole research and according to the conceptual framework of the present study, urban morphological indicators affecting energy consumption in various types are discussed. Accordingly, the dependent variables are the amount of heating and cooling energy, which according to the research goal approach, the cooling energy demand will be considered as the principle, and variables independent of the physical characteristics of urban settlements, morphological issues such as buildings, blocks and corridors. It will include that some changes have been slightly overlooked in order to converge as well as to avoid convexity of the

assessment. According to the mentioned indicators, in order to achieve the objectives of the research, the indicators to be evaluated as pairs of elements extracted from morphological elements are: height, building density, surface to volume ratio, building surface ratio, block structure and product, width and the direction of passages as well as the orientation of urban masses. According to the type of research and its objectives and also to prevent scatterbrained, only quantitative evaluations have been done and in the field of qualitative evaluation such as the pattern of passages or the factor of human behavior, future researches can be addressed. By examining real examples, using energy and climate simulation and analysis software, as well as modeling the type of energy adaptation mentioned and the rate of reflection or absorption of building surfaces, optimal policies will be proposed to demonstrate energy use. It should be noted that due to the breadth of the concept of sustainability, it requires a hierarchical structuring of analysis in the components of urban morphology. In the final step, after recognizing the morphology of conventional types in Khorramshahr, the current state of morphology tissue is simulated and analyzed, and after considering the structure explained in the parametric scenario morphology, the optimal state is selected as the optimal model and based on one of the selected cases is re-analyzed. In this case, the difference between the optimal state and the current state of the evaluated variables explains the difference and the effect of each of them and determines the effective range based on the basic indicators (Table 1).

Khorramshahr City with an area of 201215 square kilometers between 48 degrees and one minute to 48 degrees and 30 minutes' east longitude of the

Table 1: Research framework of energy consumption mechanism of urban settlements with sustainable development approach

Components, indicators in explaining the mechanism of energy consumption of urban settlements with a sustainable development approach with emphasis on morphology		
Concept	Component	Indicator
Energy	Energy consumption in the building	Heating energy Cooling energy Lighting
	Block structure	Morpho-types structure Building height Building Density
Morphology	Building	Volume to surface ratio Building surface ratio Building orientation

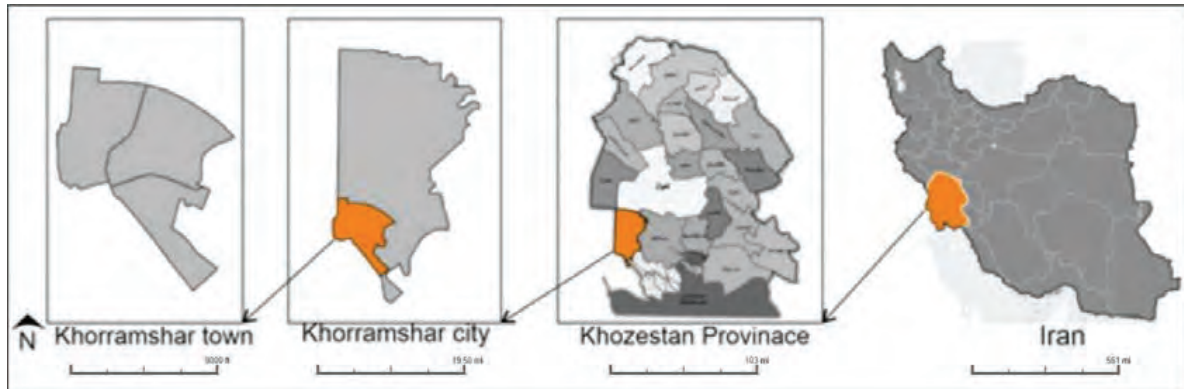


Fig. 1: Geographical location of Khorramshahr in the country and Khuzestan province

Greenwich meridian and 30 degrees and 19 minutes to 30 degrees and 58 minutes' north latitude of the equator at the southwestern tip of Khuzestan province as Fig. 1 shows:

In terms of topography and natural features of the city, the city is relatively flat in general, in the northern part of the Karun River is the highest point of the city with a height of 4.2 meters above sea level and the lowest point in the southern part with a height of 50 centimeters above sea level. The study of the urban context of the current situation in Khorramshahr indicates that the major central parts of the city include fine-grained fabric and a combination of fine-grained and inter granular (Statistical center of Iran, 2018). The hybrid and coarse-grained fabric occur mainly in newer development areas, and the coarse-grained fabric is most concentrated in the southern part and parts in the eastern part of the city. It should be noted that the morphology of the studied types based on research indicators and typology in modern urban planning based on LSE sources includes the morphological evaluations, which has been done according to the explanation of the combined scenario based on the principle of sustainability (Fig. 2).

## RESULT AND DISCUSSION

### *Conceptual variables examined*

#### *Variables evaluated in urban morphology*

According to Pont and Haupt (2005) research, diagram tools express general density variables in urban geography. This tool is actually called the Space Mate. With this tool, the urban environment

can be expressed using density variables such as ground floor index, gross space index, open space and layer ratio. These quantities can both describe diverse urban environments and build character. For the four variables mentioned in Space Mate, which prove the geography of an urban site, it is possible to determine the differences between an area on a medium scale and other areas, in fact, these variables explain the mass is quite useful and effective. The floor space index, also known as building density, indicates the intensity of the built environment. This variable is also widely reflected in the design and development as amount of floor made, which can indicate the amount of base balance and the amount of load. The gross space index, in other words, the level of coverage or occupation is also proportional to the amount of construction, which proves the relationship between built and unbuilt space. The ratio of open space does not describe the intensity of the ground, and finally the number of floors is the average number of floors in the environment. The proposed scenarios are introduced in the form of three-dimensional simulations of them as well as numerical data of the mentioned specifications for each scenario, two groups are introduced, which specifically need a combined scenario for this research and also in order to optimize and obtain a more accurate result. Therefore, the following can be explained as the main structure of the scenario; the morphology of Khorramshahr urban types, like most modern cities, includes the morphology of routine urban types, which is shown as follows. (Figs. 3 and 4)

In order to get better acquainted with the selected



Fig. 2: Location of urban morphotypes in Khorramshahr



Fig. 3: Sample images of Khorramshahr urban morphotypes from Google Earth

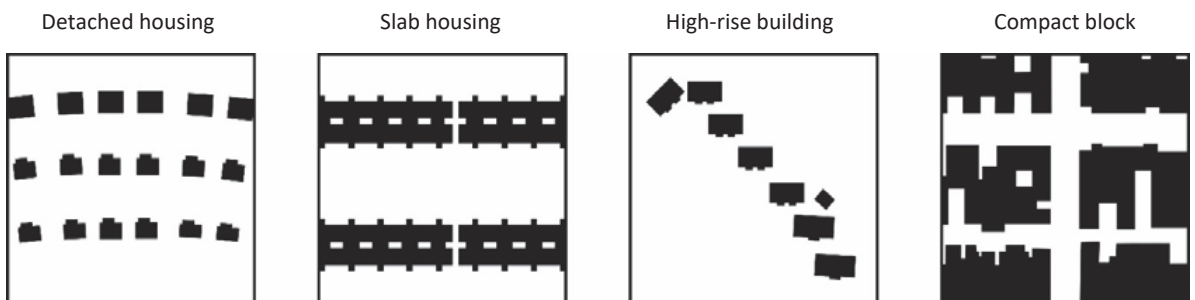


Fig. 4: Figure ground map of the urban morphotypes of Khorramshahr

Table 2: Proposed classes for optimizing energy consumption for compact block castings in Khorramshahr

Building density ratio	Building surface coverage	Number of floors	Gross area of all floors (Square meters)	Ground floor area (Square meters)	Length of the building (Meter)
1	12%	8	1530	196	14
1	16%	6	1530	256	16
1	25%	4	1530	400	20

types as morphotype, additional explanations of the morphology of selected types, including location, background and a brief cognition of the construction conditions and the existence of this part of the urban context are explained. In addition, due to the goal setting, to provide the optimal state of density in each type, taking into account the existing criteria on the one hand, the potential and the need for the physical body of the city to expand vertically on the other hand and the inherent properties of the types in order to check the optimal state of each form, the number of proposed layers for scenario making is expressed in each section.

#### *Compact block morphotype*

The compactness of the compact apartment types with the housing type of normal apartments has the highest mass in urban fabric, especially in the checkered grid. This type of types, depending on the per capita level and population, which include between 4 to 8 classes. According to the case study sample, the number of floors 4, 6 and 8 will be considered in the analysis (Table 2).

The case for a compact apartment in Khorramshahr has been selected from Taleghani alley located in a city block in the north of the city center, which is designed in a checkerboard pattern and its axes are north-south and east-west. Taleghani alley has 18 blocks of 250 to 270 meters, which are often divided into two pieces of 140 and 130 meters as front plate and back plate, which are often one or two floors. The building fabric in this area is a villa with a yard and the ownership of the area belongs to individuals. In terms of density, these buildings are in medium density.

#### *High-rise buildings*

The type of high-rise building, which is more commonly known as residential complexes as discrete blocks, has a homogeneity and structure similar to other buildings, which can be clearly created

in the type of mass orientation and location in the complex. In the city of Khorramshahr, according to the assumed approach, the number of floors is 20, 24 and 32 (Table 3).

To study the current status of the urban fabric of Khorramshahr, Melli Bank residential buildings were selected according to its design and layout (not the height of the buildings). These buildings, which are located in the central part of the city, include 7 blocks, each of which consists of three floors of 2 units with a pilot. The ground of these blocks is 200 meters. The length of the block is 20 meters and its width is 10 meters. Its height to the roof is 10.23 meter. As it showed on Figs. 3 and 4, 6 of the 7 blocks are located in the northwest-southeast direction. Due to the prevailing northwest wind direction, the wind enters the northwest corner of the blocks and in terms of sunlight in the direction southwest has direct sunlight. In terms of density, these structures were in medium density.

#### *Slab housing*

Slab housing type, which is clearly known for its continuous mass type as well as its composition and diverse orientation, has the highest residential density. Therefore, due to the mass density and the specific form type, it is of great importance in the analysis. For this reason, consider the number of floors 12, 16, and 20. (Table 4)

A sample of a slab housing morphotype in Khorramshahr was selected from the residential buildings of Mehr Farhangian in the southwest of the city and along the boulevard route to Abadan with a northeast-southwest arrangement. This part of the urban fabric is the first inaugurated Mehr housing project in the province and was put into operation in 2011. The dominant type of the complex consists of 450 square meters and the yard of the villa is without external walls and with vegetation with an area of 219 square meters. The height of each 4-unit block is about 8 meters.



Table 3: Proposed classes for optimizing energy consumption for high-rise building castings in Khorramshahr

Building density ratio	Building surface coverage	Number of floors	Gross area of all floors (Square meters)	Ground floor area (Square meters)	Length of the building (Meter)
5	25%	20	800	400	20
6	25%	24	9600	400	20
8	25%	32	12800	400	20

Table 4: Proposed classes for optimizing energy consumption for sheet formwork in Khorramshahr

Building density ratio	Building surface coverage	Number of floors	Gross area of all floors (Square meters)	Ground floor area (Square meters)	Length of the building (Meter)
3	25%	12	4800	400	20
4	25%	16	6400	400	20
5	25%	20	8000	400	20

Table 5: Proposed classes for optimizing energy consumption for discrete castings in Khorramshahr

Building density ratio	Building surface coverage	Number of floors	Gross area of all floors (Square meters)	Ground floor area (Square meters)	Length of the building (Meter)
1	30%	3	1530	486	22
1	42%	2	1530	676	26
1	56%	1	1530	900	30

### Detached housing

This type is practically opposite to the type of villa housing with the number of floors, 1 to 3, which depending on the type of density can be a combination of separate units of duplex. According to the city of Khorramshahr, by considering the intrinsic characteristics of this types, 2 to 3 floors can be considered (Table 5).

The selected discrete form in the urban fabric of Khorramshahr has been selected from the residential buildings of the Army Air Force located in the southern part of the city and along the axis of Ali Ibn Abitaleb. This section includes the residential houses of naval personnel (Khorramshahr Naval Barracks). These buildings are inside the military zone and therefore it is not possible to produce images other than satellite images. These buildings are built as a one-story open-air villa without walls with an area of 340 square meters and a height of 4 meters. In this section, selected types which were introduced, in the Space environment of ENVI-Met4 software, three-dimensional modeling has been done and with climatic data obtained from Climate Consultant software for 2021, in the two time periods (summer

solstice, winter solstice and sultry month of the year), in each case for 48 hours similar to the climatic sari. In this simulation, vegetation, materials and heat from urban transportation and heat generated by buildings are ignored and only the effect of mass on the creation and change of micro-climate is considered. The results of the simulation are presented in the format of two-dimensional and three-dimensional maps, tables, and graphs. Based on the information obtained from this step, the evaluation of the morphological effect of the types in creating the microclimate around them, which leads to an increase or reduce energy consumption in buildings, will be done.

The simulation was performed for each of the four types for 48 hours for the hottest and coldest day of the year and July as the sultry month of the year. Thermal maps and 3D images of simulation results for the hottest day of the year (June 22) at 15:00 (warmest hour) and the coldest day of the year (December 22) at 5:00 (coldest hour) And the sultry day of the year (July 21) are at 15:00. Also, diagrams and tables of changes of each of the four parameters during 24 hours for selected types and average 24 hours simulation of temperature, wind speed, relative



humidity, absolute humidity and average radiation temperature in the space around the masses in the form Figs and tables are given.

Using this information, it is possible to observe and compare the behavior of microclimate due to the presence of each of these types of building types in the city of Khorramshahr. The comparison of these committees in a way represents the best type of construction from the point of view of sustainable urban design, in which the principle of energy efficiency is discussed from this concept, and it can be

suggested which type of construction in this region in terms of energy efficiency, others are better or vice versa. Therefore, this is important as the first step in achieving a sustainable urban design model. The simulation output performed in Envy Matt software in Leonardo environment is presented in three modes of 2 dimensional (2D) and 3 Dimensional (3D) maps, tables and Figures in the first part of the 2D and 3D thermal graphics, the relative humidity and specific humidity of the four morphotypes introduced on the hottest, coldest and sultry days of the year. (Figs. 5 to 8)

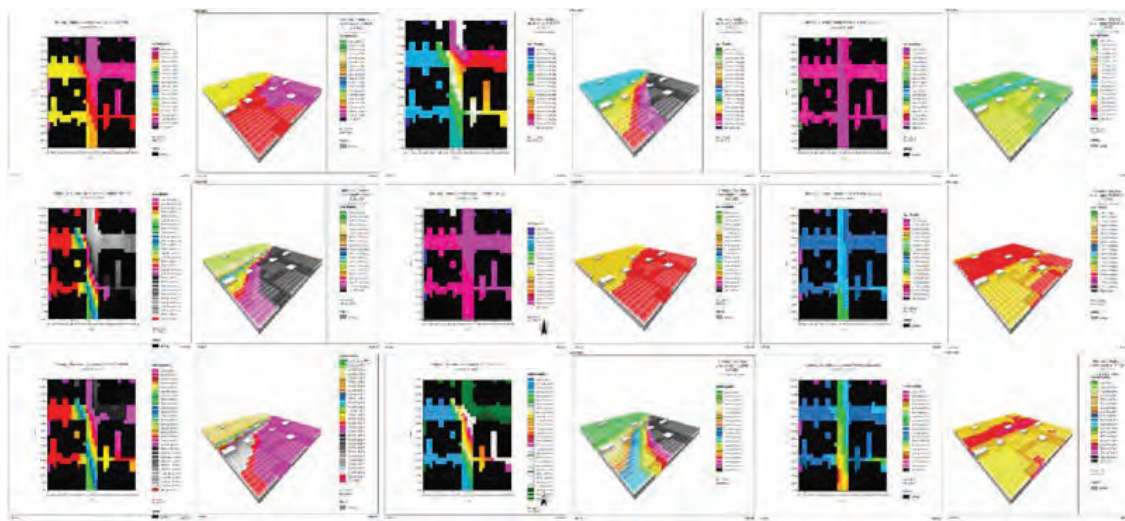


Fig. 5: 3D thermal model and map, specific humidity and relative humidity resulting from simulation of the hottest, coldest and sultry day of the year for compact building type.

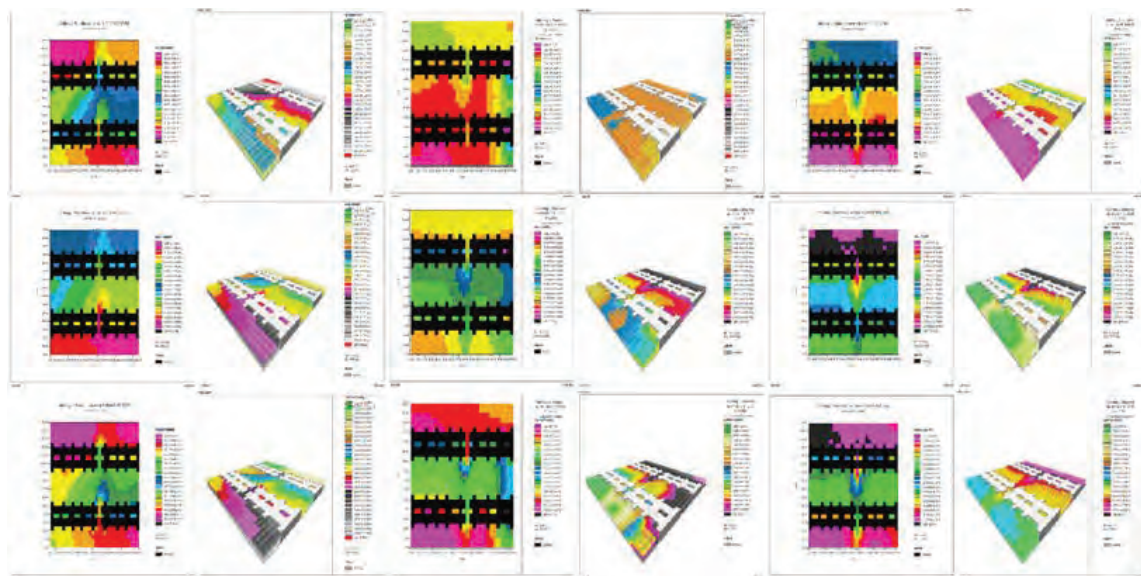


Fig. 6: 3D thermal model and map, specific humidity and relative humidity resulting from simulation of the hottest, coldest and sultry day of the year for slab housing type.

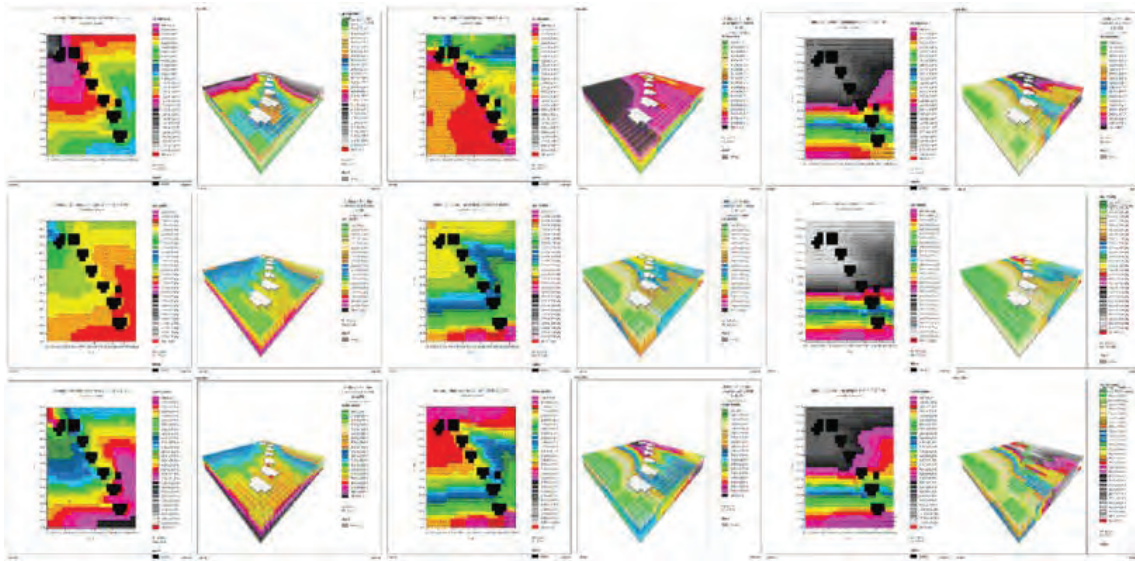


Fig. 7: 3D thermal model and map, specific humidity and relative humidity resulting from simulation of the hottest, coldest and sultry day of the year for high-rise type

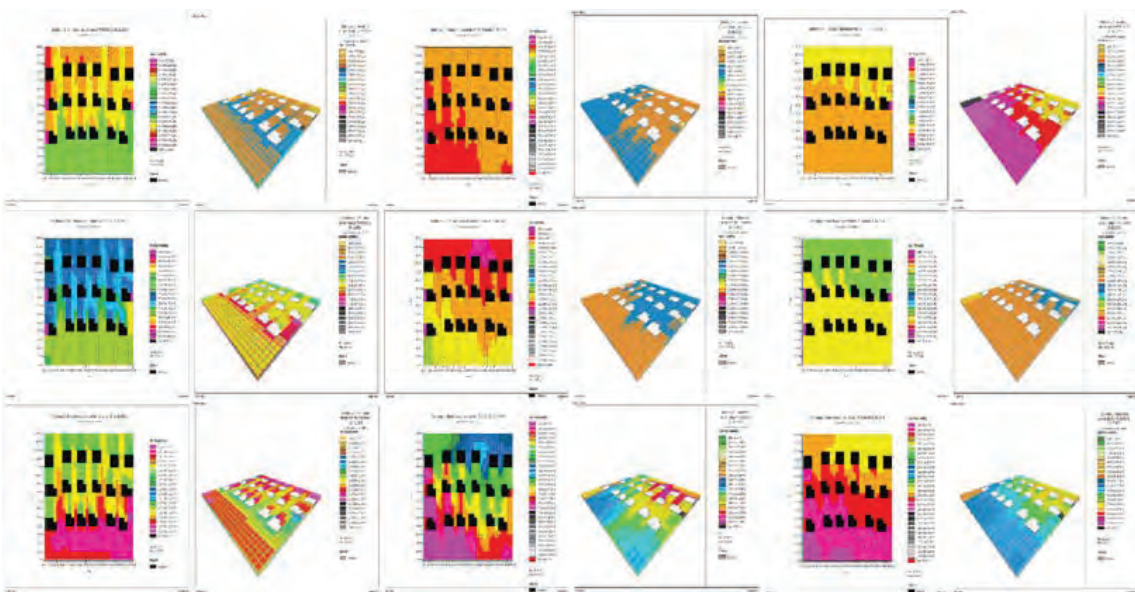


Fig. 8: 3D thermal model and map, specific humidity and relative humidity resulting from simulation of the hottest, coldest and sultry day of the year for detached housing type

In this series of two-dimensional and three-dimensional images, the differences created on cold, hot and sultry days in micro-climatic parameters are quite visible. However, in order to evaluate and examine these changes and values accurately, it is necessary to bring them in graphs and more precisely

in the form of tables and evaluate the situation in the simulated condition (Fig. 9). The simulation results of the air temperature around the buildings based on the above diagram show that the compact mold in the summer has caused the highest air temperature around the buildings. The high-rise type is the second

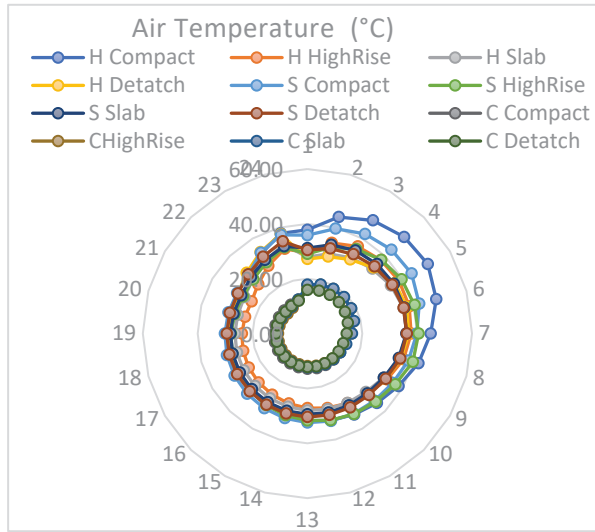


Fig. 9: Air temperature on the hottest, coldest and sultriest day of the year in the form of four morphotypes in the current situation

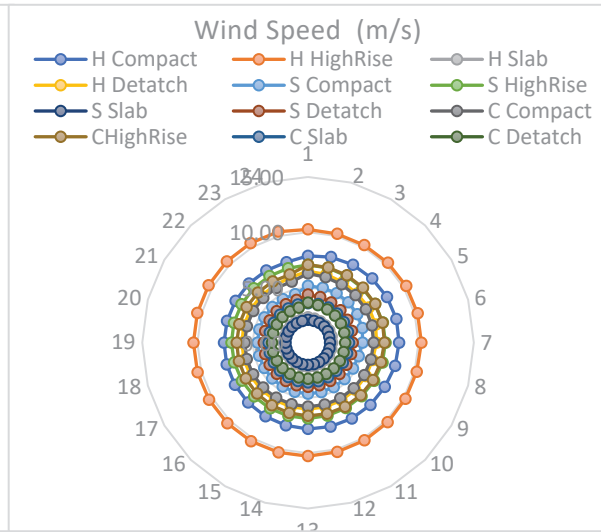


Fig. 10: Wind Speed on the hottest, coldest and sultriest day of the year in the form of four morphotypes in the current situation

case in creating a high animal in its vicinity. The lowest temperature on the hottest day with short distances is related to the slab housing and detached morphotypes. Given the temperature desirability of the cold season in this climate, the results of the simulation of the coldest day of the year due to its proximity to the comfort range, will not be analyzed and the focus will be on the hottest and sultriest day (Fig 10). The results show that the wind speed created around the high-rise morphotype, with a difference from other types, has the highest rate on the hottest day. Subsequent cases with shorter intervals and related to the hottest day of the compact type, the sultry and coldest day of the high rise. The lowest wind speed is also considered to be a sheet and the hottest and sultriest day. Although the separate calculation of the calculated parameters shows different, varied and sometimes even contradictory results for some morphotypes, so to determine the comprehensive and general conditions, it is necessary to calculate the overall result of all micro-climatic parameters due to the placement of types in the urban fabric. Ranking position, comparison and introduction of how the overall impact of each morphology on the microclimate of the surrounding climate are shown in Fig. 11. Specific moisture amount evaluations results showed that the highest amount of moisture in the space around the types is compact and occurs on the hottest day of the year. The second row in

specific moisture is again related to the same shape and on the sultriest day. Regarding this parameter, as can be seen in the diagram, except for the sunny and sultry days for the higher types, which show a slight difference from other types and days, the rest of the values are recorded very close to each other. The study of these parameters separately has the advantage that if a specific targeting is considered and the focus is on micro-climatic conditions or a specific parameter, thus it is possible to focus on changes in a particular parameter and the amount created in the space around the masses to approached the ideal rate (Fig. 12). The distribution of the simulation results explains the short and consecutive distances between the types and the recorded days. In this parameter, high-rise and compact morphotypes are observed with the difference of hours in the highest amount of relative humidity in the surrounding air. Also, the lowest relative humidity on the hottest day for slab and detached housing is showed. Differences in the amount of moisture recorded, as well as changes in this amount at different hours for each cast, indicate the possibility of further evaluation and investigation for this parameter. By focus on the relative humidity values in different conditions, different types and more days, it will give more reasoned results to comment on the mechanism of massification and microclimate behavior in following it (Fig. 13).

The mean radiation temperature is one of the



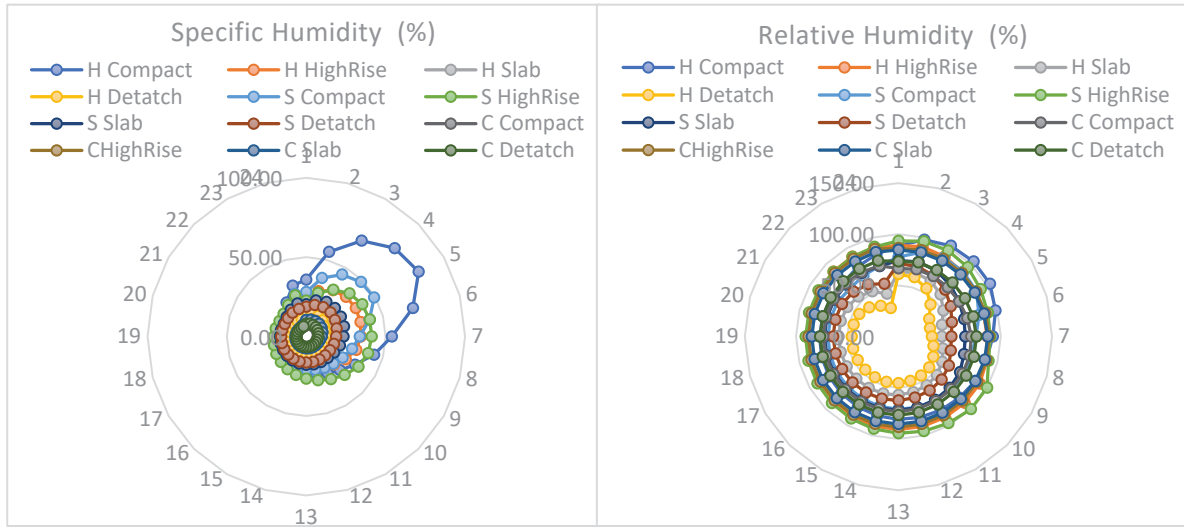


Fig. 11: Specific Humidity on the hottest, coldest and sultriest day of the year in the form of four morphotypes in the current situation

Fig. 12: Relative Humidity on the hottest, coldest and sultriest day of the year in the form of four morphotypes in the current situation

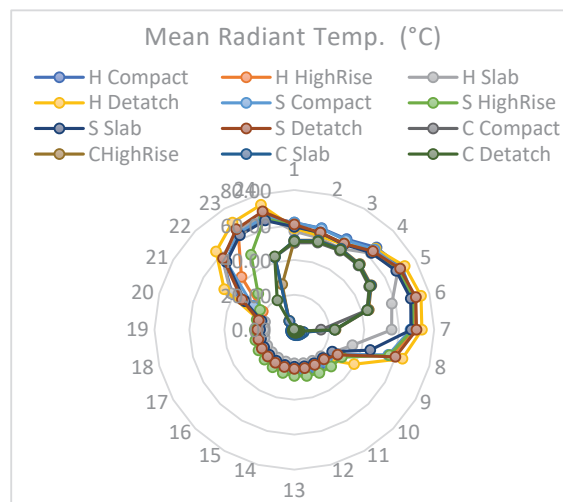


Fig. 13: Mean Radiant Temp on the hottest, coldest and sultriest day of the year in the form of four morphotypes in the current situation

important factors affecting the amount of energy required inside the building. This rate is usually highest in areas with low shading and orientation without considering the solar mask. Therefore, by increasing the density and choosing the correct and optimal orientation for passages and parts, this parameter can be reduced to a minimum and its adverse effects on the amount of energy consumption required inside the building can be reduced. The results indicate the highest rate for the discrete morphotypes, which is related to the lack of shading and the required

density. Other differences in values show the lowest on the coldest day and are about the same for all four morphotypes (Fig. 14).

Comparing the average of each parameter during the simulation between morphotypes, regarding the air temperature parameter, it seems that on the coldest day of the year, there is no significant difference between the temperatures created around the types. However, the trend line drawn in the diagram shows the changes that occurred on hot and sultry days in the air temperature between

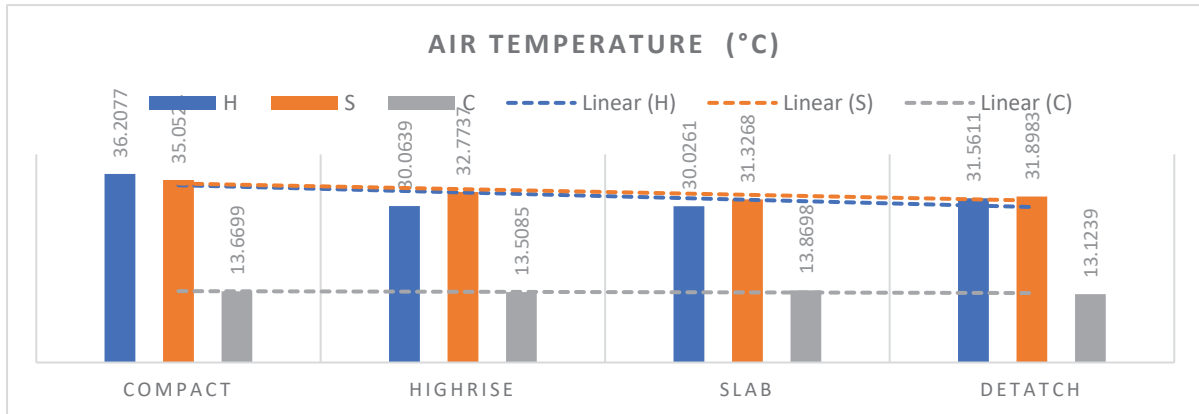


Fig. 14: Comparison of average air temperature from simulation performed on the hottest, coldest and sultriest days of the year between four selected morphotypes

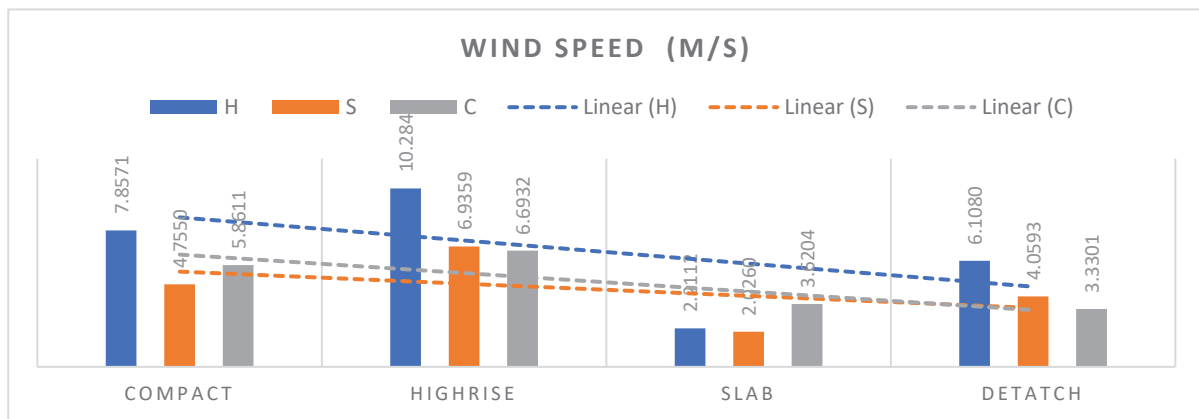


Fig. 15: Comparison of average wind speed from simulation performed on the hottest, coldest and sultriest days of the year between four selected morphotypes

the morphotypes. Compact and detached wedges have the highest air temperature in both the hottest day and the sultriest day compared to the two types of slab and high-rise, which can have a significant impact on the selection of the desired shape for this situation (Fig. 14).

The comparison (Fig. 15) shows the average wind speed. In general, it seems the highest wind speed on all simulated days around the high-rise type. The lowest value also occurs with a significant difference in the type of slab. The two types of detached and compact are placed between the two with less difference and close to each other.

The lowest average specific humidity content is also observed in two types of detached and slab housing. Compacted block morphotype have the highest specific humidity content around

them. Cocaine greatly reduces the difference and considering the values of other parameters of the compacted block type (Fig. 16).

By studying the diagram of the average relative humidity and also considering the existing trend line, the types have caused the highest to the lowest relative humidity to be high-rise, compact, slab and detached, respectively. But in general, there is not much distance in these values, such as specific humidity, which is related to the definition of these two parameters and their computational behavior. (Fig. 17).

The average radiation temperature in the four morphotypes studied, in contrast to the 24-hour chart studied in the previous section, does not show a significant difference. Therefore, by arguing this diagram, it can be claimed that the behavior of this



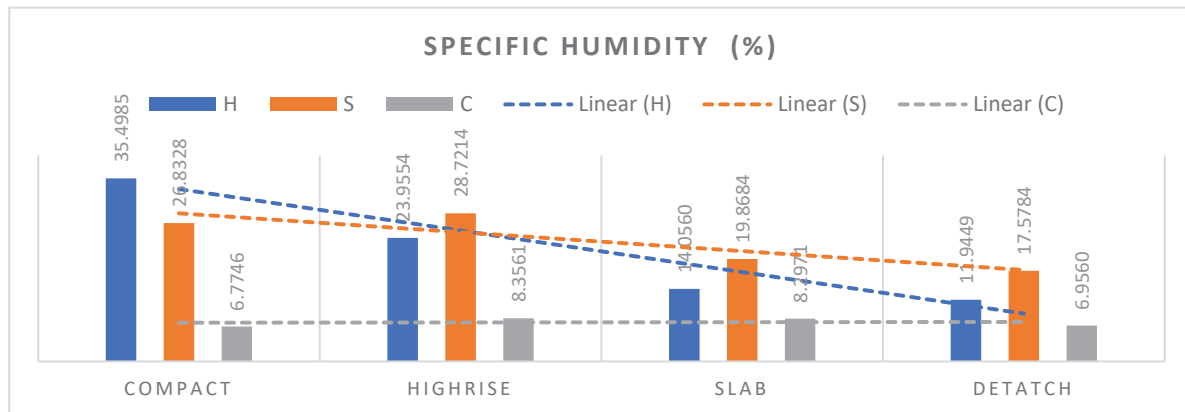


Fig. 16: Comparison of average specific humidity from simulation performed on the hottest, coldest and sultriest days of the year between four selected morphotypes

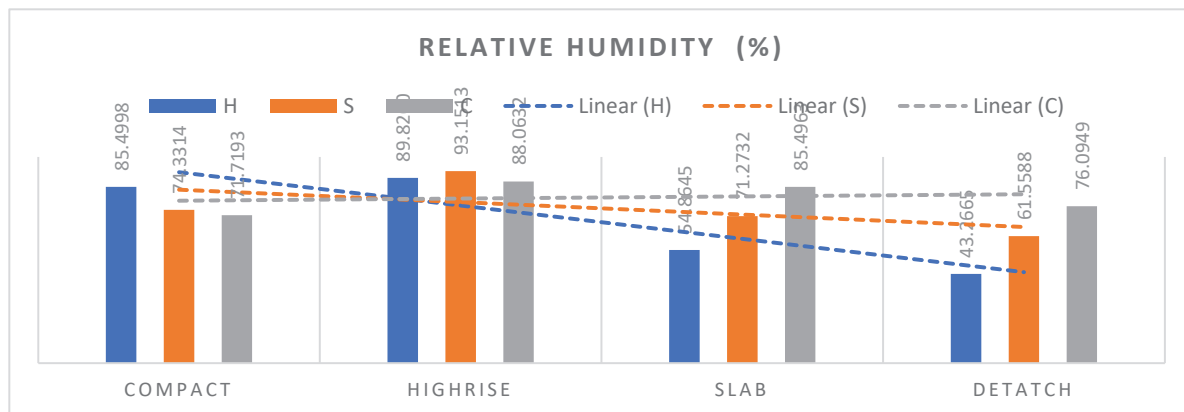


Fig. 17: Comparison of average relative humidity from simulation performed on the hottest, coldest and sultriest days of the year between four selected morphotypes

parameter is almost the same among all four cases. Therefore, it should be noted that the intensity of this parameter should not be ignored during critical hours. The table below shows the calculated average of the simulation results for each micro-climatic parameter on the hottest, coldest and sultriest day of the year for four detached, slab, high-rise and compact morphotypes (Fig. 18). To determine the condition of the morphotypes relative to each other regarding their behavior in micro-climate production, the results of critical hours (warmest and coldest hours) are evaluated. Finally, by examining the average of each parameter for each morphotypes on the desired day and comparatively comparing the results with

each other (according to the optimal amount of each parameter in relation to its effect on the microclimate of the season), and assigning a ranking weight to each morphotype and each parameter, the weighted average of each item, which includes all 5 parameters mentioned in the previous section, indicates the ranking position of the morphologies in the Table 6.

The result of the weighted ratings given to each parameter regarding the simulation results of each mold is given in the Table 7. The collective average of these weights, which includes cold and hot season data, indicates the ranking among the selected morphotypes from Khorramshahr in creating and changing the microclimate around them with the

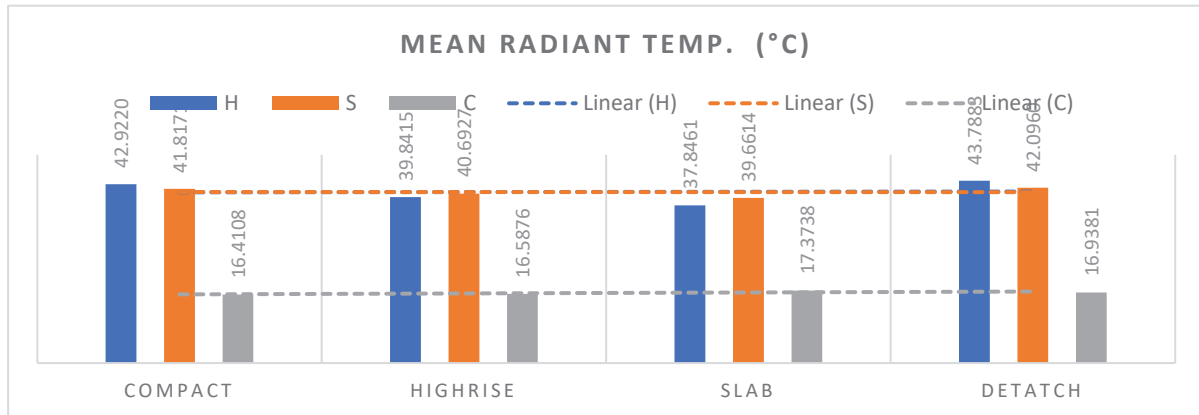


Fig. 18: Comparison of average mean radiation temp from simulation performed on the hottest, coldest and sultriest days of the year between four selected morphotypes

Table 6: Mean results of microclimate parameters in four morphotypes and ranking and weighting of evaluation results

	RW*	Compact	RW	HighRise	RW	Slab	RW	Detatch
<b>S</b> Air Temperature (°C)	3	36.2077	1	30.0639	1	30.0261	2	31.5611
Wind Speed (m/s)	3	7.8571	4	10.2846	1	2.2112	2	6.1080
Specific Humidity (%)	4	35.4985	3	23.9554	2	14.0560	1	11.9449
Relative Humidity (%)	3	85.4998	4	89.8200	2	54.8645	1	43.2665
Mean Radiant Temp. (°C)	3	42.9220	2	39.8415	1	37.8461	4	43.7883
<b>H</b> Air Temperature (°C)	4	35.0524	3	32.7737	1	31.3268	2	31.8983
Wind Speed (m/s)	3	4.7550	4	6.9359	1	2.0260	2	4.0593
Specific Humidity (%)	3	26.8328	4	28.7214	2	19.8684	1	17.5784
Relative Humidity (%)	3	74.3314	4	93.1513	2	71.2732	1	61.5588
Mean Radiant Temp. (°C)	3	41.8171	2	40.6927	1	39.6614	4	42.0960
<b>W</b> Air Temperature (°C)	3	13.6699	2	13.5085	4	13.8698	2	13.1239
Wind Speed (m/s)	3	5.8611	4	6.6932	2	3.6204	2	3.3301
Specific Humidity (%)	4	6.7746	4	8.3561	3	8.2971	1	6.9560
Relative Humidity (%)	1	71.7193	4	88.0632	3	85.4963	1	76.0949
Mean Radiant Temp. (°C)	1	16.4108	2	16.5876	4	17.3738	3	16.9381

\*RW (Rank Weight): The weight assigned to each parameter based on its acquired rank  
 Green represents the first, blue the second, orange the third and red the fourth rank

Table 7: Final ranking status of selected morphotypes

Morphotype	Hottest day					Sultriest day					Coldest day					Average	Final Rate
	AT	WS	SH	RH	MRT	AT	WS	SH	RH	MRT	AT	WS	SH	RH	MRT		
Compact	3	3	4	3	3	4	3	3	3	3	3	3	1	1	1	2.73	3
HighRise	1	4	3	4	2	3	4	4	4	2	2	4	4	4	2	3.13	4
Slab	1	1	2	2	1	1	1	2	2	1	4	2	3	3	4	2.00	2
Detatch	2	2	1	1	4	2	2	1	1	4	1	1	2	2	3	1.93	1

energy efficiency approach. Of the four morphotypes studied, high-rise buildings have the worst impact and detached buildings have the best impact on the microclimate formed around them.

Based on results, each ranking weight of morphotypes showed the situation of morphotypes behavior in front of micro climatic parameters in

Khorramshahr. Unlike the previous researches that was reviewed, the evaluation of climatic parameters by considering the type of morphology in the systematic structure can provide more accurate results. From four types that studied, High-rise buildings with an average of 3.13 worst impact and detached housing with an average of 1.93 have the

best impact on the microclimate formed around them, which obviously energy efficiency according to climatic indicators and microclimate metrics can be emphasized the principle of optimal limit. Although the accuracy of the evaluation and the type of information evaluated can be considered as limitations in this type of research, the systematic structure of this type of research method can also help future researches.

## CONCLUSION

According to the background, it can be pointed out that most of these researches have been done on analytical structure in the concept of a model and conceptual framework by introducing indicators and precise parameters practically taking into account all interfering parameters in most researches. The sustainable urban form, emphasized in these current studies, with the compactness of urban masses subject has not been practically examined and systematically analyzed. For this reason, in this study, a sample of urban fabric in the form of morphotypes has been evaluated. The results showed that assigning a ranking weight to each morphotype for each parameter, the average weight of each case, which included all 5 parameters, indicated the rank position of morphotypes in Khorramshahr. Of the four types studied, high-rise buildings with an average of 3.13 and detached buildings with an average of 1.93 had the worst and best impact on the small climate formed around them, which obviously could be considered according to climatic indicators and microclimatic metrics could be emphasized the principle of optimal limit. Also, the findings showed the energy consumption status according to the evaluation of morphological variables. It was the morphotypes as well as the climatic parameters that had determined the specific results of each case and also provided the appropriate type and rating. In future research, by explaining the optimal model of urban fabric stability model based on the concept of sustainable morphology, each morphotypes in the optimal state can be evaluated. The final ranking of the current status of the selected morphotypes indicates that, in terms of the microclimate created around the building blocks, which results in the energy efficiency of the buildings, the morphotypes was higher than other types. Therefore, based on the knowledge and evaluation of Khorramshahr urban fabric with regard

to energy in urban morphology and the principle of urban fabric stability, to present the optimal model of urban design, the findings of the current research showed the energy consumption status according to the evaluation of morphological variables. It was the morphotypes as well as the climatic parameters that have determined the specific results of each case and also provided the appropriate type and rating. In future research, by explaining the optimal model of urban fabric stability model based on the concept of sustainable morphology, each morphotypes in the optimal state can be evaluated. Attention should be paid to the structure of the research, which subsequently its physical model can be simulated. In the continuation, the mentioned model enters the stage of strategy-making as well as the formulation of general policies, which can be considered as a pseudo-model in the urban areas of Khorramshahr and in the general view in the city.

## AUTHOR CONTRIBUTIONS

H. Karamouzian performed the literature review, experimental design, analyzed and interpreted the data, prepared the manuscript text, and manuscript edition. S. Zanganeh Shahraki and R. Farhodi supervised the experiments, literature review, data compiling and manuscript preparation

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## CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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#### ABBREVIATIONS (NOMENCLATURE)

AT	Air Temperature (°C)
WS	Wind Speed (m/s)
SH	Specific Humidity (%)
RH	Relative Humidity (%)
MRT	Mean Radiant Temp. (°C)
H Compact	Compact Building Hottest Day
S Compact	Compact Building Sultriest day
C Compact	Compact Building Coldest day

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REVIEW PAPER

A systematic literature review on community relocation in the historic urban contexts

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ABSTRACT

Community relocation could be voluntary or forced, but such change in the composition of inhabitants can endanger the historic urban context and its cultural significance. So, finding the answer to these questions is crucial: What are the main factors for relocation in historic urban contexts, and are these areas affected differently? This paper presented and discussed the results of a systematic literature review of international English-language publications. Databases such as Scopus, ICOMOS Open Archive, and UNESCO digital library were investigated to reveal the main factors for community relocation in the historic urban contexts. Results revealed a frequent focus in metropolitan regions and major cities worldwide between 1987 and 2021. The multiplicity of non-environmental relocation factors was also noticeable. Despite the commonalities of factors for community relocation worldwide, the type and effect of the relocation differed between the historic urban context and other urban contexts. The interaction of two main factors, namely economics and policies, was found to affect the process of community relocation in the historic urban context the most. Forced relocation was more predominant than voluntary relocation in historic urban contexts. However, the existing relations between internal and external factors that drive relocation must be further investigated. This research identified and charted how the local community relocation in historic urban contexts that are reflected in scholars' publications. It also defined a theoretical framework on the factors of community relocation in these contexts and their interrelation, which is vital for both urban and heritage studies as well as planning practices.

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## INTRODUCTION

The relationship between the local community and cultural heritage, tangible and intangible, is fundamental to conserve the historic urban context. The relocation and/or exodus of communities have proven to contribute to decreased care and investment (Evans and Grosicki, 2017; Hollander et al., 2018), and degradation and abandonment (Ryberg-Webster, 2016; Tintěra et al., 2018), which can lead to urban decline. In urban literature, the urban decline is often associated with reduced population and decreased quality in the city, especially in neighbourhoods (Hollander, 2013). The impact of this phenomenon is assumed to be more destructive in historic urban contexts, as these are areas inhabited over centuries, where the bonds between man and environment grew in consolidation. Varied international charters, conventions, and recommendations such as the European Charter of the Architectural Heritage, 1975, HUL 2011 and Burra Charter, emphasize the importance of heritage conservation, tangible and intangible, to the sustainability of communities in historic urban contexts. Although the relocation of communities is noted to occur more frequently in historic urban contexts (Abastante et al., 2020), seldom is the research focused on revealing and discussing its factors (Xie and Batunova, 2019). Yet, when timely identified, the factors can be tackled and the relocation or exodus of communities prevented, and resources could be spent differently (Ryberg-Webster and Ashley, 2018). The relocation of communities concerns their change in residence, which can either be voluntary or involuntary. Involuntary relocation occurs by force (Goetz, 2002; Hatch, 2021), while voluntary mobility is the household's choice (Hatch, 2021). But when it occurs in a historic urban context, its impacts could be long-lasting and destructive for both the communities and heritage conservation, as their values are often interdependent. By means of a systematic literature review, this article seeks to recognize the factors of population relocation in historic urban contexts and their possible differences from other urban contexts. Additionally, this study wants to recognize how this phenomenon has been investigated. Although various countries have differences in social and economic conditions, are there any commonalities among the relocation factors in the historic urban contexts? So, the paper is structured as follows: First, the research method

is introduced. Second, the outcomes are explained in two separate sections. The first section presents the chronological, geographical, demographic, and methodological distribution of research evidence. The second section deduces a theoretical framework, defining the factors of community relocation and their relations. For this purpose, the results from the literature review are purposely integrated and put out of context to facilitate theory development. This study has been carried out in Isfahan, Iran in 2021.

## METHODOLOGY

This research applied the qualitative method to perform a systematic literature review, taking as samples the publications available in the Scopus database, ICOMOS Open Archive, and UNESCO digital library until 2021. The publications were selected based on the use of keywords: "relocation", "neglect", "urban decline", "depopulation", "shrinkage", and "vacant" in either title, abstract, or keywords. By means of the snowball method, other publications referenced by these publications were also included in this literature review. Overall, 476 publications were identified, containing journal articles, book chapters, articles in conference proceedings, and workshop reports. The screening protocol, inclusion/exclusion criteria, and the process of its application are further detailed in the PRISMA diagram (Moher et al., 2009) (Fig. 1). Finally, 84 publications were selected for review and categorized, making use of Mendeley.

## RESULTS

### A. Overview of studies on Community Relocation in Historic Urban Context

In the first step of the analysis, the results are presented over time and place. There is growing attention to communities' relocation in historic urban contexts, particularly after 2014, summing up to a total of 67% publications (56 out of 84). The U.S studies are more constant, while European is more recent and intensive (Fig. 2). Asian studies are more scattered but present. The cities taken as case studies are mostly located in North America (36%) and Europe (33%), followed by Asia (19%) (Fig. 3). Particularly, Philadelphia (USA), Cleveland (USA), Lisbon (Portugal), Venice (Italy), and Istanbul (Turkey) have been chosen more as a case study in research evidence. Worth noting that in all research evidence,

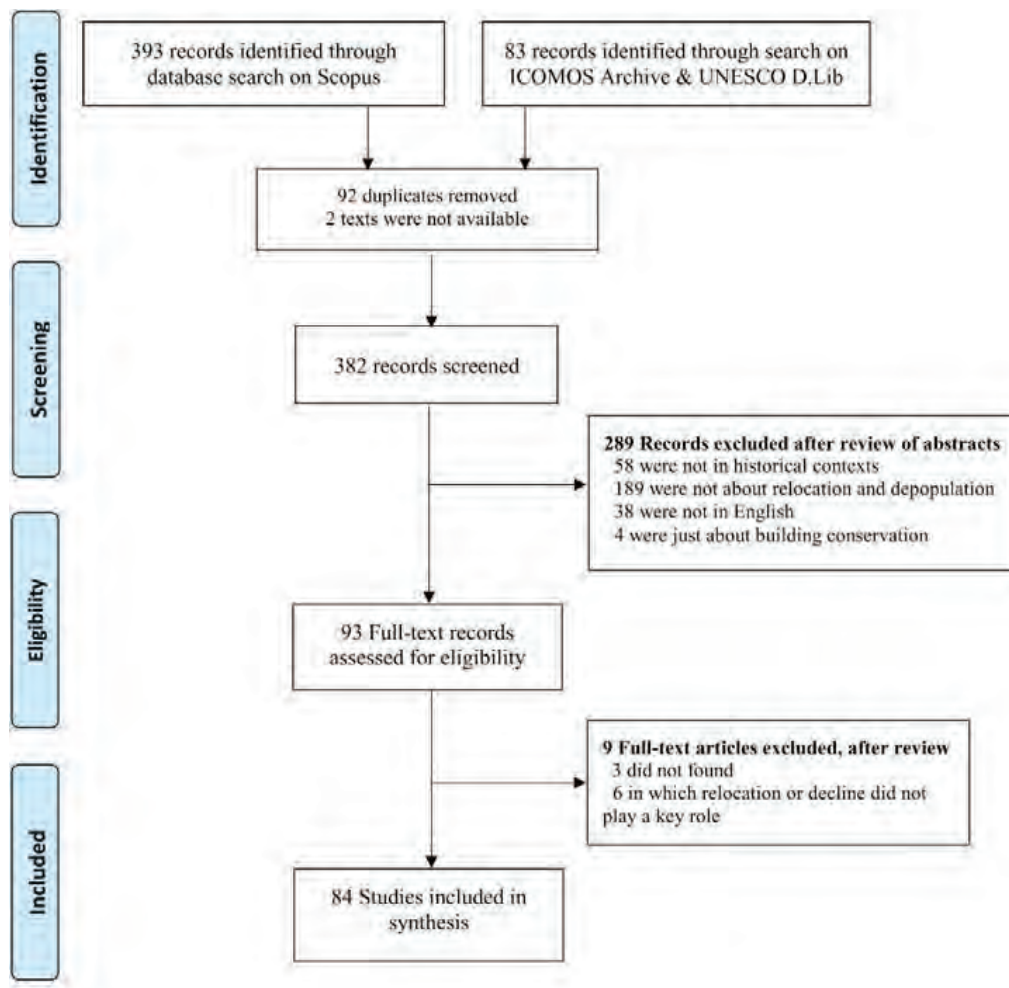


Fig. 1: PRISMA diagram of the literature search and final inclusion of publications

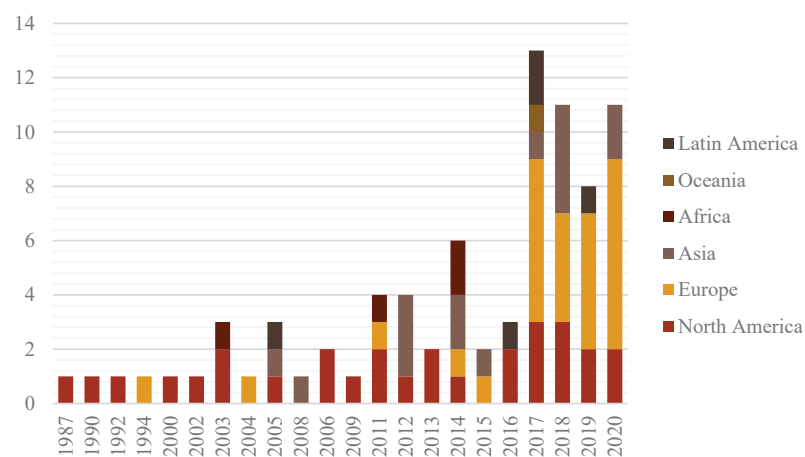


Fig. 2: Matching the place and time of the case studies

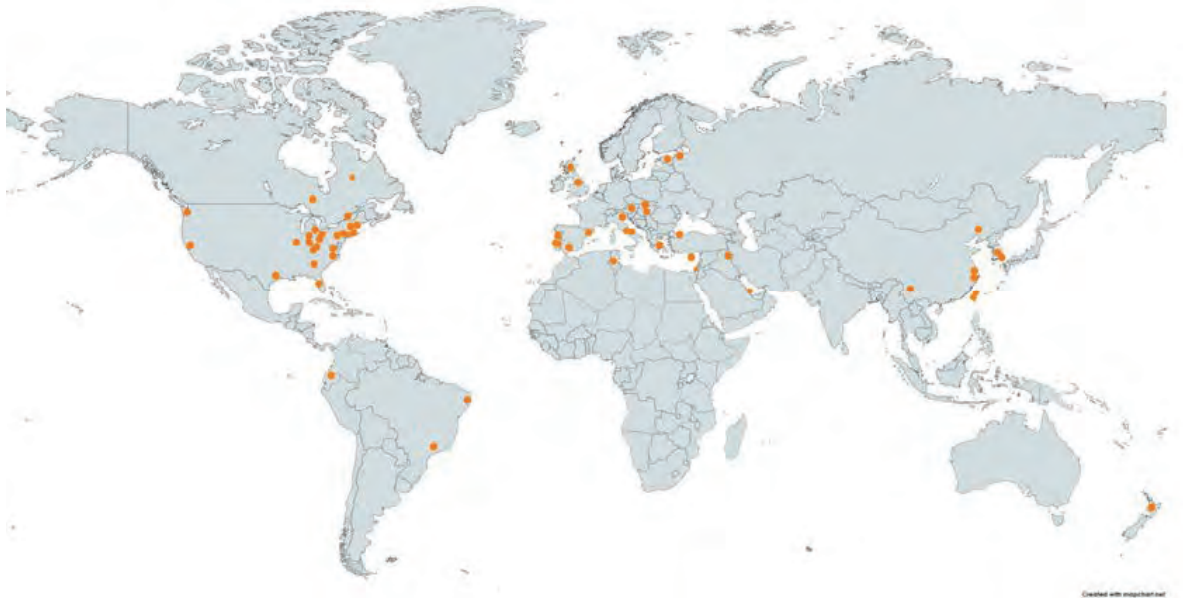


Fig. 3: Geographical distribution of case studies. Every orange dot represents a location.

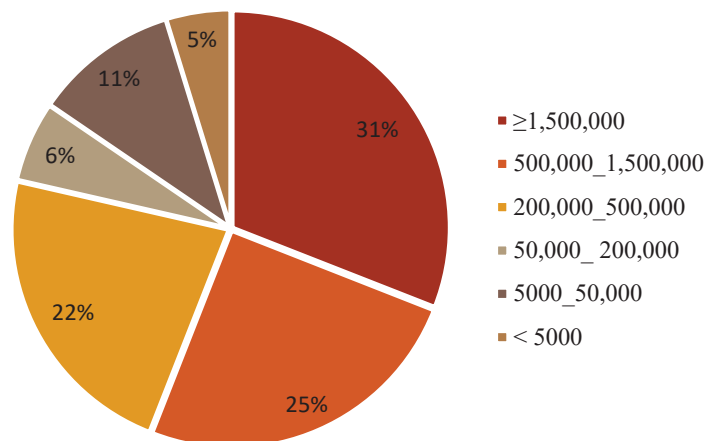


Fig. 4: Distribution of the publications concerning population statistics (Each case's population was brought from the country's national institute of statistics or United Nations data)

relocation has occurred during the 20th and/or 21st centuries.

When comparing publications focused on a specific case study, results revealed that the smaller the population, the fewer the publications (Fig. 4). In fact, 56% of the cities taken as case studies have a population over 500,000, and among them, 31% have a population of over 1.5 million.

Community relocation in historic urban contexts

was not the only term used by scholars. Instead, (population) 'decline' was highly used, followed by urban decline which is related to urban shrinkage (Kitchin and Thrift, 2009; Kaufman, 2012; Hollander *et al.*, 2018; Mínguez *et al.*, 2019; Xie and Batunova, 2019). Terms such as 'depopulation', 'population loss', or 'relocate' directly refer to the change in population (Salvati and De Rosa, 2014; Yakubu *et al.*, 2017; Hollander *et al.*, 2018; Tintěra *et al.*, 2018; Lopes *et*

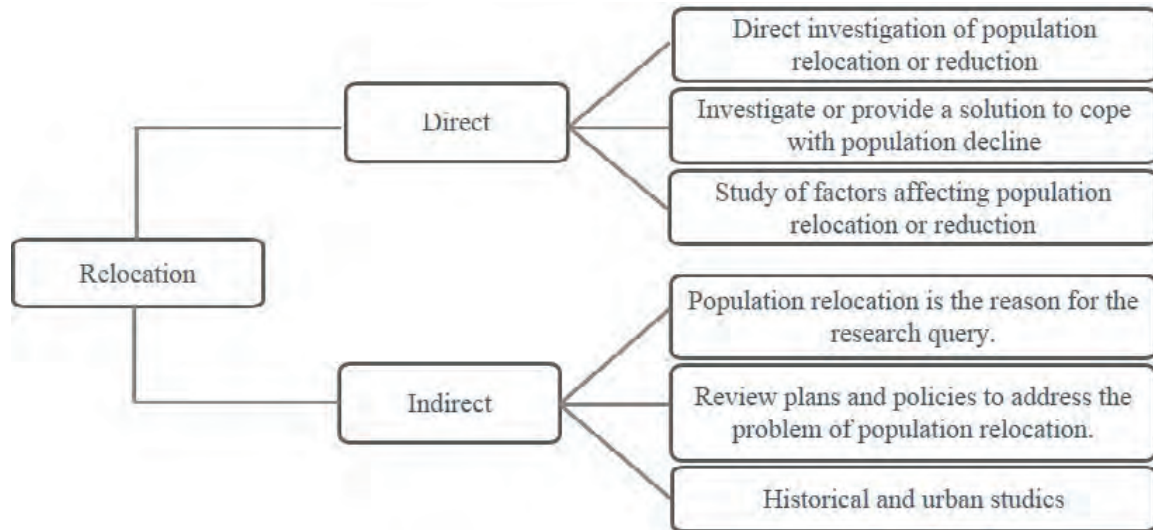


Fig. 5: Categories of addressing community relocation in historic urban contexts

*al.*, 2019; Sampson *et al.*, 2019; Medeiros and van der Zwet, 2020); While, others like ‘abandoned’, derelict’, or ‘vacant’, address its effects and consequences (Davis, 2002; McCabe, 2005; Knowles, 2009; Boussaa, 2014; Huang and Chen, 2014; Appler, 2016; Arslanli *et al.*, 2017; Ryberg-Webster and Kinahan, 2017; Bose, 2018; Fischer and Osterreicher, 2019; Kim and Lee, 2020). Terms such as ‘exodus’ or ‘displace’ were found referenced when addressing forced relocation and describing the type of movement (Xie and Batunova, 2019; Ferreira *et al.*, 2020; Sequera and Nofre, 2020; Torkington and Ribeiro, 2022). Terms such as ‘crowding out’, ‘downgrading’ and ‘deportation’, were the least mentioned among others (Berényi, 1994; Ferreira *et al.*, 2020; Jover and Díaz-Parra, 2020). So literature generally addressed the negative aspects and effects of community relocation. Most case studies (76%) have considered related changes over time. But less than half (44%) have brought up the demographic statistics (Axenov, 2014; Mínguez *et al.*, 2019). Community relocation in publications has been considered in two categories: direct (43%) and indirect (57 %) (Fig. 5). For example, the article by Griffin *et al.* (2014), which examines the solution to the problem of a declining population, was classified as indirect since the demographic change was mentioned but not researched.

Direct studies have used qualitative, quantitative, and combined research methods. Qualitative methods

ranged from in-depth to semi-in-depth interviews (Burgos-Vigna, 2017; Zanini, 2017; Ryberg-Webster and Ashley, 2018), focused group interviews (Akkar Ercan, 2011), and archival research analysing maps, images, and documents (Bowen, 2003; Phillips *et al.*, 2012; Ng, 2015; Ryberg-Webster, 2016). Quantitative methods ranged from questionnaires (Chen and Yang, 2018), and statistics (Nadalin and Iglori, 2017; Hollander *et al.*, 2018; Ferreira *et al.*, 2020; Kim and Lee, 2020). The mixed method uses a combination of the previous two (Hwang, 2014; Tintëra *et al.*, 2018; Lopes *et al.*, 2019; Mínguez *et al.*, 2019). Also, the process of studies is based on questions, hypotheses, or both. Question-based studies with the mixed method have the largest share of direct studies. No hypothesis-based studies used mixed methods for data collection (Fig. 6).

#### B. Typology of community relocation factors in the historic urban context

This section comprehensively introduces the factors that affect community relocation in historic urban contexts. These factors take different forms but are subdivided into two main categories based on their origin: environmental and non-environmental (Table 1).

##### B.1. Environmental Factors

Two environmental factors, namely natural



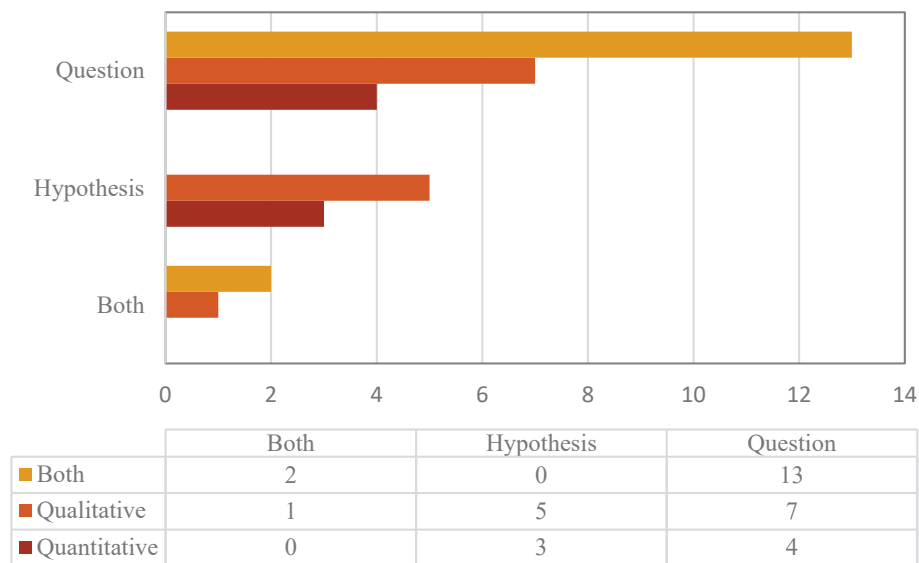


Fig. 6: Comparison of research types and data collection methods in direct studies

disasters and location, have caused population displacement (forced relocation), from historic urban contexts. Hurricanes like Katrina and Rita in New Orleans (Barnett and Beckman, 2006), earthquakes (Baiocchi *et al.*, 2017; Caffio, 2018) and landslides (Yapeng, 2018) are examples of the first factor. The location of the historic 'Piazzo' area of Biella has created problems resulting in dissatisfaction among residents and their relocation, mostly due to its access and lack of adaptation to the current lifestyle are the main (Abastante *et al.*, 2020). Despite the effect of environmental factors, local communities and their attachment to cultural heritage are proven to have an undeniable role in keeping the community away from relocation. For example, some residents in Princeville, North Carolina, have been displaced due to several floods. But the deep attachment between the locals and their ancestral legacy powered them to fight against forced relocation. As a result, they returned to their homes after consolidation and reconstruction (Phillips *et al.*, 2012).

### B.2. Non-environmental Factors

**Economic change:** A significant part of these changes includes financial crises. Financial crises are sometimes the initiator and the major cause of population exodus, and sometimes its aggravator (Abastante *et al.*, 2020), as it has consequences

such as reduced job opportunities (Greenbaum, 1990; Hollander, 2013; Tintěra *et al.*, 2018). Reduction of job opportunities and income will decrease micro-and macro-scale investments, even in building maintenance (Chai and Choi, 2011), and increase poverty in addition to the progression of urban decline. For instance, the Great Depression in the United States has been one of the causes of demographic change in historic neighbourhoods (Ryberg-Webster, 2016). Industrial change, which is a branch of economic change, is effective on population decline in historic urban contexts, especially if this change is related to a transition from production to consumption (Gosling, 1992; Hwang, 2014). Examples include the industrial decline in Youngstown and the relocation of middle-class white households to the surrounding countryside (Morckel, 2017) or the post-industrial urban decline in Philadelphia (Davis, 2002). Change in industrial patterns sometimes leads to rising unemployment, abandoned spaces, and problems in the surrounding neighbourhoods (London, 2003). It has sometimes occurred in the form of deindustrialization in historic urban contexts. For example, the closure of factories and related companies as well as their relocation from the Gongrencun region to the outskirts of Shenyang, China, occurred at the behest of the local government and was intended to reduce pollution

and improve economic conditions. Nevertheless, it destroyed job opportunities and left industrial heritage buildings vacant (Chai and Choi, 2011). In contrast, industrialization attracted people from small cities and villages to large cities (Lung Ping Yee *et al.*, 2005) and set the stage for community replacement.

*Policy:* Political decisions on a national and international scale, which seem to have macro impacts, have an undeniable role in relocating the original inhabitants. International politics, of which war is an outcome, not only have cross-border implications but also internal consequences and conflicts for the countries involved. For example, World War II and its political consequences, such as racial discrimination, the expulsion of Jews, the rise of communists to power, and exile, led to increased migration from the historic city of Budapest (Berényi, 1994; Szívós, 2015). The Arab-Jewish war in Palestine forced almost the entire Arab population to leave the historic city of Jaffa (Aleksandrowicz *et al.*, 2017). So, the effect of some political issues, like the war, on the community relocation from different contexts is the same. Sometimes, gaining independence has had economic consequences and consequently a negative impact on the population of historic areas. In Estonia, for example, after the secession of the Soviet Union and the establishment of independence, the Valga city's industry deteriorated due to the Soviet troops' departure, hence acting as one of the factors that reduced the population of this city (Tintěra *et al.*, 2018). In some cases, despite positive approaches and goals, the domestic policies of governments, such as desegregation and policies to end racial discrimination (Bowen, 2003; Heathcott, 2006; Nix and Weiner, 2011; Spirou *et al.*, 2020) or to change immigration law (Ryberg-Webster, 2019) have led to the displacement of social groups and the emptying of historic sections. It is worth mentioning that many of these communities, such as the black community of Jackson Ward (Bowen, 2003), had adapted to the existing conditions and grown within themselves. But with the change of laws, they lost a significant part of their population, and their economic situation also changed. In the United States, for example, with the change and advancement of civil and legal rights, some educational and employment restrictions were removed, which led to the departure and displacement of the population, especially the youth and the more affluent classes (Longoria and Rogers,

2013). Changes in spending leisure time among the middle and lower classes after the fall of fascism and the privatization and liberalization of the banking system in Portugal in 1984 led to the possibility of rapid local housing expansion on the outskirts of Lisbon and a reduction in the population of the historic urban context (Sequera and Nofre, 2020).

*Development strategies:* urban development strategies and policies are crucial in community relocation from historic urban contexts. In many cases, these strategies, which are often governmental top-down decisions, do not consider local communities (Chen and Yang, 2018). For example, the order to install sprinklers in homes in Seattle led to the eviction of many tenants by landlords and the emptying of homes (Ryberg-Webster, 2019). Also, the permission for home evacuation by a landlord after six months and an increase in tenants displacement in Portugal (Torkington and Ribeiro, 2022), and the unsuccessful experience of urban renewal in the Woodlands (Gillick, 2017) are some examples of inattention to this serious issue. Here, developments leading to the relocation are divided into two main groups:

1: *The development regardless of the historic urban context and its cultural significance:* Examples of this group include urban renewal (Greenbaum, 1990; Gillick, 2017), the threat of demolition of part of the city, like what happened in Treasure Hill, Taipei (Ng, 2015), and the development of other areas regardless of its adverse effects on the historic urban context. The latter, in particular, acts as an incentive to relocate, especially by middle- and upper-income individuals, and to accelerate the decline in the historic centre (Arslanli *et al.*, 2017). The growth of retailing in the modern part and the increase in suburban shopping malls in Boston resulted in the emptying of the historic centre, which was once the retail core of the city (Cutrufo, 2011). In João Pessoa, the city expansion has been followed by new urban centres establishment and gradually reduced the economic influence of the historic primary nucleus (Raony Silva and Donegan, 2019). Suburban development (Gillick, 2017), even the construction of new houses or villas on the outskirts (Boussaa, 2014; Davoodi and Dağlı, 2019), is a factor of community relocation from historic urban contexts. Particularly governmental actions for development regardless of problems in the historic urban context (Clarke and Corten, 2011; D Boussaa, 2014; Kim and Lee,

Table 1: Typology of community relocation factors in the historic urban context

Environmental Factors		Non-environmental Factors						
Natural disasters	Location	Economic change		Policy		Development strategies		
		Financial crises	Industrial change	National	International	Regardless of the historic urban context	Concerning the historic urban context	
								Discrimination    Dissatisfaction
E.g. Hurricanes	E.g. Difficult access due to location	E.g. Income change	E.g. deindustrialization	E.g. desegregation	E.g. War	E.g. Urban renewal	E.g. Gentrification, Touristification	

2020). In some cases, the negligence in development projects, such as the construction of highways and routes which would pass through the historic urban context or cut off its communication with other sections, caused a vast population displacement or even the stagnation of the historic urban context (Bowen, 2003; Nix and Weiner, 2011; Arslanli *et al.*, 2017; Gillick, 2017; Spirou *et al.*, 2020). Sometimes, convenient location and economic-spatial values of the historic urban context are the factors that create pressure. Since poor communities cannot make the best economic and social use of their land, their neighbourhoods are often the target group for economic development projects (Werkneh, 2017). Some consequences of applying such a policy to San Francisco are rising land and rental prices or rapid development of tourism, leading to the continued exodus of Chinese ethnic groups and the threat to the neighbourhood's authenticity (Xie and Batunova, 2019). Urban development projects like urban refurbishment (Maher and Haas, 1987) or renewal projects (Keating, 2000), displaced the deprived community in favour of the affluent one. In some cases, the government considers the historic urban context as a source of obstacles to urban development. For example, under the pretext of the population increase and the emergence of social and health problems, they have displaced the community to new houses outside the historic neighbourhood (Queirós and Borges Pereira, 2018). Rising crime rates are other pretexts for destroying some historic urban contexts and in particular residential complexes. So, the active social system that supports the residents is socially and psychologically destroyed. In Techwood, families who lived close to neighbours, friends, and relatives and formed networks of trust and social capital were displaced and could not return after redevelopment (Keating, 2000).

*2: Development aimed at improving the historic urban context:* Some projects to improve, rehabilitate, or develop the historic urban context lead to displacement or increase social pressure. Because regardless of the importance of preserving the social fabric, their focus was to protect the physical one (Ammon, 2018; Yang and Hsu, 2018). In the historic centre of Quito, Ecuador, the implementation of public space recovery policies after its inscription on the UNESCO World Heritage List, led to the expulsion of informal street businesses from the historic urban context (Burgos-Vigna, 2017). The regeneration project in the Harlem area, New York, caused the loss of dignity of people who were forced to leave the community in which they lived (Werkneh, 2017). Even state-led urban development policies in historic Mexico City have pushed up land and housing prices, making it difficult for low-income people to continue living in these areas (López-Morales *et al.*, 2016). Some regeneration and gentrification projects, which are classified as modernization and development policies, have been accompanied by working-class replacement with the middle and upper classes (Akkar Ercan, 2011; Ammon, 2018; Mínguez *et al.*, 2019; Jover and Díaz-Parra, 2020). Gentrification has numerous material and social aspects. But the reduction, relocation, and fragmentation of social groups and the elimination of small businesses, which contribute to society's intangible heritage, are among the main negative consequences of gentrification in the historic urban context (Atkinson, 2004; Werkneh, 2017; Ammon, 2018). López-Morales *et al.*, (2016) indicate a variety of gentrification projects that have taken place in some Latin American historic centres and have relocated social groups. Axenov (2014) in comparison between post-socialist and western cities, argues that gentrification and social degradation occur in post-socialist cities simultaneously. On the

contrary, the two processes occur successively in Western cities. Since gentrified neighbourhoods are often selected by the residents of the same city for living, not by people of other places (Atkinson, 2004), gentrification projects are more repel the existing population than attract new ones to the city. In many cases, the term touristification is used in conjunction with gentrification. Scholars, such as Zanini (2017), refer to it as tourism gentrification. In some cases, such as Lisbon, the increasing demand for tourist accommodation has led to gentrification (Lopes *et al.*, 2019). Still, others distinguish them. Sequera and Nofre (2020) consider gentrification and touristification as two separate categories with fundamental differences because the type of behaviour and relationship of the tourists in the neighbourhood differs from the people who live in it. Jover and Díaz-Parra (2020) argue that the relationship between gentrification, transnational gentrification, and touristification is dialectic. They claim that tourists and lifestyle migrants are parts of the same phenomenon, but their impact on urban space is different. Gentrification seeks to create a place for the residence of social groups, while touristification looks for commercial and economic goals, and the presence of the community does not make sense (Jover and Díaz-Parra, 2020). It is clear that the target group of gentrification projects has a long-term presence, unlike touristification. So, in the present study, cases concerning tourism gentrification or an increase in tourist demand are classified as touristification. The growth of guesthouses alongside traditional hotel management in cities like Lisbon is considerable, which evidences the increase of touristification in this city. Although the process of establishing guesthouses in the historic centre of Lisbon boosted its economy, rising housing prices have led to the growth of migration from the historic centre. This immigrant group is often the working class and pensioners (Ferreira *et al.*, 2020). Interestingly, in some instances, touristification has even displaced a population that previously inhabited the historic district through gentrification. In Seville, Spain, for example, after 2010, tourism has displaced those residents who replaced the working class in the 1990s through gentrification (Mínguez *et al.*, 2019). In Lisbon, touristification has thwarted the efforts of gentrification and studentification (Sequera and Nofre, 2020). Excessive tourist presence and its

consequences have led to a decrease in the population in varied historic contexts (Dominguez, 2017; Zanini, 2017; Yang and Hsu, 2018; Bertocchi and Visentin, 2019; Grima, 2017). In addition to reducing the number of locals and displacing them, tourism has other effects such as increasing the presence of non-locals, reducing the sense of security and comfort of the residents, increasing noise pollution, increasing the cost of living in the historic centre, increasing housing prices and reducing the number of available houses, decreasing non-tourism-related jobs and abolition of traditional retail and local shops and their replacement by modern restaurants and bars (Mu Zhe and Xinhao Wang, 2012; Ng, 2015; Dominguez, 2017; Zanini, 2017; Bertocchi and Visentin, 2019; Jover and Díaz-Parra, 2020). Even environmental consequences such as pollution of water resources due to population growth and consumption could be regarded as the consequences of touristification (Mu Zhe and Xinhao Wang, 2012). Thus, there is a risk of changing local customs and culture, reducing the residents' sense of belonging, creating dissatisfaction among community members, and losing tangible and intangible heritage. Touristification, as one of the newest methods of development, has political dimensions as well. These include the possibility of attracting transnational capital by local governments and intensifying regional competition between cities (Sequera and Nofre, 2020). The economic profitability of governments is one of the reasons why the stability of local communities in these sectors is not a priority for policymakers. Interestingly, tourism causes the displacement of all three poor, middle, and wealthy classes living in the historic region. This is how an unstable population forces a fixed population to move.

*Discrimination:* Discrimination can come from the policies of governments or people's attitudes. The importance of this becomes even more vivid when we know that race even affects property valuations (Werkneh, 2017). Since historic urban contexts are home to minorities in many cases, displacement due to discrimination is also considerable in these areas. The racist attitudes toward religious or racial minorities (Todeschini, 2003; Toprak *et al.*, 2017) and events such as the White flight in Cleveland (Ryberg-Webster and Ashley, 2018) are examples of human attitudes found researched in literature. Governmental order for the Japanese to leave the Chinese neighbourhood

of Seattle (Ryberg-Webster, 2019), discriminatory treatment by the local federal aid agency of Latin smokers in Ybor and exacerbating the consequences of unemployment there (Greenbaum, 1990), and destruction of public housing belonging to blacks in Harlem that once embodied black culture and art (Werkneh, 2017) are some examples of governmental discriminatory policies. Thus in many cases, the government's discriminatory attitude or the change of discriminatory policies, such as desegregation, have been associated with economic consequences that have caused the community relocation.

*The dissatisfaction of residents:* The feeling of dissatisfaction is the outcome of various factors. Simultaneously, it is a fundamental factor of community displacement in the historic urban context and its acceleration. Not allocating enough portion for the community to comment on the historic urban context, like the impossibility of repairing houses, is an example (Hwang, 2014). Creating new architectural structures in conflict with the historical sector, entry of strangers and cars into the environment, and intensifying the feeling of alienation among residents is another (M. Amin, 2018). This factor is significant because the evidence shows that lack of interest in the living environment is one of the reasons for the reduction of its care and its subsequent abandonment (Heathcott, 2006). Some historic urban contexts, such as the historic centre of Sao Paulo, have failed to prevent the spread of urban problems and consequently have lost their appeal to the community (Nadalin and Iglori, 2017). However, creating a vibrant and dynamic environment or having an attachment to the place, despite the environment's existing difficulties, has prevented relocation (Greenbaum, 1990; Phillips et al., 2012; Kristianova and Jaszczak, 2020).

## DISCUSSION

Environmental factors are general and repeated worldwide. But, the dominance of non-environmental factors is quite explicit. The adaptation of the various factors and the timing of relocation at different points lead us to other common factors behind them: World Wars I and II, which had a direct impact on policies and consequently discrimination, especially in Europe (Berényi, 1994; Szívós, 2015), Post-World War II developments such as urban renewal and the

expansion of suburbanization (Gillick, 2017), historic centres' evacuation and migrating to new areas due to changing lifestyles and standards in the twentieth century and the inconsistency of historic districts with it (Burgos-Vigna, 2017; Zanini, 2017; Abastante et al., 2020; Sequera and Nofre, 2020; Boussaa, 2021), dominance of car use (Gonzalez et al., 2005; Sequera and Nofre, 2020) and inconsistency of access routes to historic areas with this increase of car use (Abastante et al., 2020), increased traffic in historic districts (Arslanli et al., 2017), even the change of commercial transportation systems (London, 2003; Naeem, 2008; Arslanli et al., 2017) and, finally, increasing attention to the physical characteristics of historic cities and their registration in UNESCO from the 1970s onwards had consequences such as touristification (Burgos-Vigna, 2017; Dominguez, 2017; Zanini, 2017; Yang and Hsu, 2018). Such evidence not only reveals the impact of the global community on the historic urban context but also shows the predictability of community relocation, which plays an essential role in urban heritage management. All these indicate the multidimensional nature of this process. Although the extent of relocation factors' impact in historic urban contexts is highly dependent on the characteristics of the context, like culture, geography, or politics, the findings show that relocation factors in historic urban contexts have commonalities worldwide as they have the same sources. The interaction of two main factors in the non-environmental category, namely economic change and policies, affects the process of community relocation and forms its factors in the historic urban context (Fig. 7).

The outcomes of this interrelationship increase the probability of relocation. Income reduction (London, 2003; Tintěra et al., 2018; Abastante et al., 2020), deficiencies in the historic sector and its decreased liveability (Clarke and Corten, 2011; Longoria and Rogers, 2013; Yakubu et al., 2017; Kim and Lee, 2020), the appeal of new development compared with the historic urban context (Gonzalez et al., 2005; Boussaa, 2014; Arslanli et al., 2017; Davoodi and Dağlı, 2019; Abastante et al., 2020), and even policies like gentrification and touristification have no result other than generating dissatisfaction among the community. The feeling that makes people leave this place. These factors



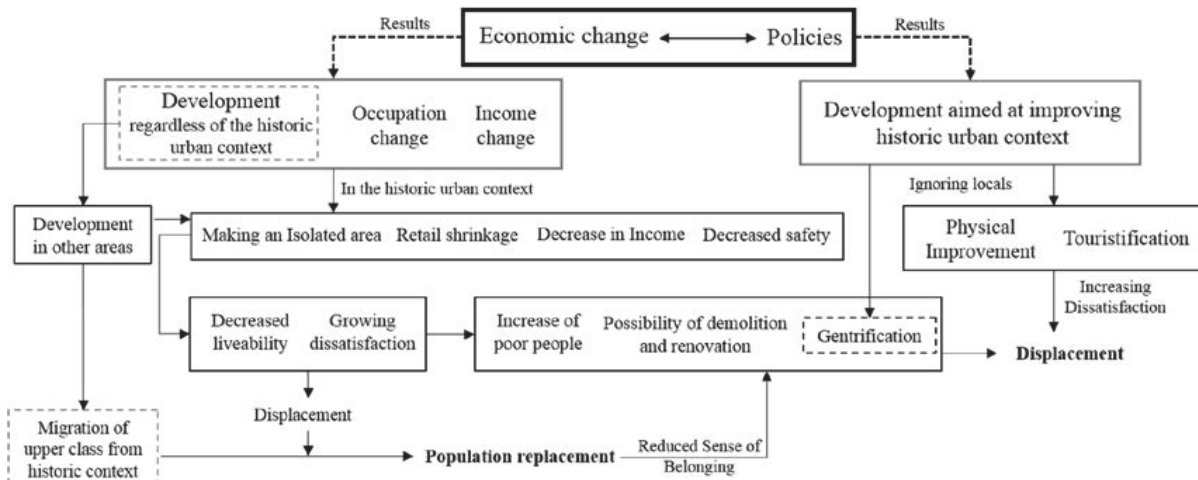


Fig. 7: The modality of interaction between economic change and policies on the relocation of historic urban context community

are generally the result of state decision-making, regardless of the locals and their right to participate (Keating, 2000; Hwang, 2014; López-Morales *et al.*, 2016; Burgos-Vigna, 2017; M. Amin, 2018). While the consequences directly affect them. Population replacement is one of the outcomes of community relocation from a historic urban context. Replacement can happen several times, in an area and for various reasons, such as in the Latin Quarter in Ybor (Greenbaum, 1990). The significant point is that the replacement of different groups leads to a continuous change in the demographic structure of the historic urban context and reduces the sense of belonging. When the weaker strata replace the previous group, the conditions for the following replacement measures, such as gentrification, become more available (Akkar Ercan, 2011; Boussaa, 2014; Toprak *et al.*, 2017). As the inhabitants of historic urban context move, the connections of place that define 'self' and 'community' break down (Phillips *et al.*, 2012). Consequently, in addition to creating deteriorated and abandoned areas, it leads to the elimination of small and local businesses (Greenbaum, 1990; Cutrufo, 2011; Burgos-Vigna, 2017), the destruction of social networks and trust and hence social capital (Keating, 2000; Bowen, 2003; Xie and Batunova, 2019), and the threat to the authenticity and integrity of the historic urban context. The historic urban context is more prone to changes in its inhabitants' composition because of its differences. Besides general relocation factors

(like environmental factors, war, and discrimination), they encounter specific ones. For example, their structural features target them to implement special projects like clean-up and redevelopment. For example, gentrification and tourism not only do not preserve existing communities, but often displace them in favour of another group. The result is nothing but a transformation in the historic urban context's social structure. A comparison between the relocation of different social classes living in historic urban contexts elucidates that the upper classes can more easily change their residence, indicating they have a choice (Gosling, 1992; Akkar Ercan, 2011; Morckel, 2017; Toprak *et al.*, 2017). But it is the poor and vulnerable groups who, even as conditions in the historic urban context improve, are more likely to be displaced and suffer economic, social, and psychological hardship (Atkinson, 2004). For example, tenants are more likely to be forcibly relocated than landlords (Ng, 2015; Chen and Yang, 2018; Torkington and Ribeiro, 2022); however, they are more attached to the place of residence than the owners who do not live there. The continued presence of people near the valuable heritages will generate a sense of belonging and attachment in these residents and thus encourage them to invest in and protect the legacies.

## CONCLUSION

The community relocation, which is often irreversible, threatens the social capital of the cities

and, in return, endangers the authenticity, integrity, and stability in the historic urban context. Although the factors influencing this type of relocation are multidimensional and diverse, they have a joint basis in different studies. The interaction between economic change and policies underlies the evolution of other factors. But the power of social structures and local connections resists displacement. So, future studies should simultaneously consider the context-based and general factors to recognize the relocation mechanism through direct and in-depth research. How and in what process these factors have caused the community relocation has not been investigated. By taking an internal perspective, the role of various contextual factors in this process, such as geography and culture, becomes apparent. In addition, the identification of internal and external forces and confrontation between them, which are less studied, would be investigated. Subsequent research should also examine the practical solutions and seek the best practices in dealing with this problem. The effect of relocation factors on historic urban contexts is different from other urban areas, and the possibility of displacement is more. The relocation of each social class affects community composition and threatens related assets, while maintenance of social cohesion is essential to preserve urban sustainability. Although the upper-class relocation seems voluntary, it often occurs due to deficiencies and problems in the historic urban context and thus forcibly. Additionally, it leads to an increase in low-income households and a decrease in investment in these areas. Some development strategies in historic centres, such as touristification, can displace all the locals regardless of their social class. Displacement, which is involuntary and sometimes encountered by the inhabitants' resistance, leads to loss of social networks, connections between residents, respect for individuals, and a sense of belonging. Undoubtedly, the 'feeling of dissatisfaction' is the significant feeling people experience during displacement from the historic urban context. These issues indicate the importance of considering local people and the effects of policy-making on a micro and macro scale. Given the research evidence and its characteristics, this paper also provides further suggestions for future studies. It is necessary to study this phenomenon on the scale of small-sized cities

and historic villages, as the existing publications have considered major cities appreciably. Statistical and historical information is essential in data collecting, and in-depth studies with qualitative approaches are required. The geographical distribution indicates the need for increased published articles, especially in Asia, Africa, Latin America, and developing countries in general. Additionally, the subsequent research can employ the meta-analysis method for analysing research evidence quantitatively.

#### AUTHOR CONTRIBUTIONS

M. Azarnoush performed the literature review, analysed and interpreted the data, and prepared the manuscript text and edition. E. Esfanjary kenari, A. Ghaffari, and A. Pereira Roders compiled the data and manuscript preparation.

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#### CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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## ABBREVIATION

UNESCO	United Nations Educational, Scientific and Cultural Organization
ICOMOS	International Council on Monuments and Sites

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ORIGINAL RESEARCH PAPER

Investigation of spatial-physical development model based on spatial analysis, GIS and Holdren entropy model

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ABSTRACT

**BACKGROUND AND OBJECTIVES:** Irregular and unplanned development of cities has led to some difficulties with the natural environment and human well-being reflected in the inappropriate spatial structure. Perception of physical-spatial pattern leads to the invention of appropriate policies to equitable distribution of services in urban areas and achievement of balanced development. This study aims to analyze the physical-spatial pattern of the Mashhad City from 1986 to 2016 conducted based on GIS data of the census blocks of Mashhad.

**METHODS:** The current study was performed using descriptive-analytical method. In order to achieve that, spatial statistics tools including Moran coefficient, hotspots and directional distribution (standard deviational ellipse) have been used on ArcGIS PRO 2.5 software as well as Holdren model. Population is one of the prominent variables affecting growth and physical-spatial development of the city, therefore, the population has been considered as an indicator in this research.

**FINDINGS:** The obtained values of the Moran Index (1986=0.13, 1996=0.14, 2006=0.15, and 2016=0.15) represented that the population pattern of the city was clustered, compact and continuous. Likewise, Hotspots revealed high population density in the continuous area from east to northwest in addition to the neighborhoods around the Vakil Abad highway. Standard deviational ellipse of population illustrated that the population distribution was heading to northwest. Applying Holdren model and data analysis showed that Mashhad experienced the horizontal and sprawl growth.

**CONCLUSION:** Obtaining balanced future development and avoiding unplanned encroachment of the city boundary are integral issues. As a result, the current and legal city limit must be maintained and inner development and compact pattern must be implemented.

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## INTRODUCTION

In recent decades, cities, in particular metropolises, have developed unprecedentedly. In many cases, the physical growth outweighs the population one, so that the ratio of increased area exceeds the ratio of increased population. Therefore, the fertile agricultural lands are being swallowed up by physical development of cities (Noori Nejad *et al.*, 2016). As a result, the rapid growth of metropolises in both on scale and size culminates in the instability of urban life (Maleki, 2018) and the complexity of managing urban growth has become one of the most important challenges of the 21st century (Cohen, 2004). Amid the increase of population, cities expand invariably, so city limits and its physical space develop quantitatively and qualitatively (Ibrahim Zadeh and Rafi'i, 2009). Urban growth is a complex and dynamic process, moreover it involves changes in physical and functional components of built environment (Sahana *et al.*, 2018) and is affected by various indicators such as economy, society, nature, management etc. Unplanned urbanization leads to large-scale changes in land use affecting the sustenance of natural resources. Monitoring the development of the city necessitates an understanding of spatial patterns of urbanization to implement appropriate mitigation measures (Aithal and Ramachandra, 2020). In general terms, development means gradual flourishing, revealing the components of everything and the growth of something that exists, a relative attribute which is defined over time in a specific place (Papoli Yazdi and Rajabi Sanajerdi, 2017). In other words, moving from the current situation to the one in which more opportunities and facilities are provided to sharpen the society (Javaheri Taghados *et al.*, 2019). Physical expansion is described as a rise in quality and quantity of uses and physical spaces of a city in the horizontal and vertical directions over time (Bemanian and Mahmoodi Nezhad, 2008). The horizontal physical development encroaches the non-urban spaces around the city, therefore it deals with one of the most limited resources named land which is available to human beings (Gherekhlou and Zanganeh Shahraki, 2009). On the other hand, the spatial development is the embodiment of human's determined and sensible effort or their arbitrary effort in response to their needs in society (Massumi Eshkevari, 2006) and the quantitative and qualitative improvement of urban life so without considering

the multi-faceted policies such as physical, social, economic and political aspects and reinforcement of which, this kind of development will be impossible (Abdi Daneshpour, 2017). Anderson *et al.* (1996) possessed the conviction that physical and spatial developments were essential and defined urban form as the spatial pattern of human activities at a certain point in time. Therefore, the physical-spatial development can be interpreted as a process of physical growth, transformation of uses and urban activities and changes in urban per capita to meet citizens' needs (Hatami Nezhad *et al.*, 2012). The physical-spatial development might occur not only horizontal (decentralized and scattered growth) but also vertical (concentrated and compacted) (Tsai, 2005) or even the mixture of both. These patterns depending on the type of expansion they create in the city result in denser use of urban space or encroachment of non-urban space which transform the urban environment as well as surrounding countryside. Urban sprawl is described as a specific form of urban development with low-density, dispersed, auto-dependent and environmentally and socially-impacting characteristics (Hasse and Lathrop, 2003) which expands towards the margins of the city and countryside (Wassmer, 2002). As a result, vast areas of agricultural and natural lands around the city will convert and urban per capita will increase. Almost all theories about urban distribution point to the uncontrolled use of land and the uncontrolled expansion of cities in this type of development, from theories that considered the horizontal expansion of the city as a solution for future cities in response to population demands to theories Which is considered it as an unplanned and uncontrolled spatial growth (Table 1).

Harvey and Clark (1965) suggested three main types of urban sprawl patterns: ongoing scattered development with low density in large parcels, linear development (mostly non-residential activities) alongside the major highways and leapfrog development which forms nearby available areas in vacant lots close to the city. All of the types are subject to automobile and citizens have to bear the long distance (type 1 and 3) and heavy traffic (type 2). The vertical expansion or compact development was originated from Le Corbusier's idea of a radiant and contemporary city. The idea of compact city aims to enhance the quality of life, create cities

Table 1: Urban sprawl characteristics

Theorists	characteristics
Mouratidis (2017)	Low-density development can offer quietness, access to nature, higher perceived safety and cleanliness, and stronger neighbor ties
Bramley and Power (2009)	Urban sprawl can decrease land and dwelling prices, cause reduce congestion in transport
Menon (2004)	Scattered and self-reliant expansion outside of urban dense centers and around highways and suburbs
Nozzi (2003)	Unscheduled, low-density and intermittent development and functionally not connected to uses around the city
Wassmer (2002)	Low-density and scattered development to outside of the city limits and suburbs based on car
Peiser (2001)	Improper and inefficient use of land, uniform, fragmented and leapfrog development
Hadly (2000)	City expansion towards the margins and villages or alongside the motorways in an unplanned and uncontrollable way
Brueckner (2000)	The necessity for spatial development to accommodate population increase
Ewing (1997)	A partly new pattern in human settlements resulting from the aggregation of low-density, auto-dependent residential units
Doxiadis (1968)	Ecumenapolis as a horizontal city with low population density and a continuous system of buildings and neighborhoods in a universal biological complex
Lloyd Wright (1932)	Low population density as a suitable environment for the American society

with high density without the difficulties of modern ones (Newman and Kenworthy, 1989). With the introduction of sustainable development, this pattern was considered and became one of the ways of achieving ‘sustainable urban development’ (Jenks and Burgess, 2004). The compact form not only maintains the rural lands around the city but also reuses and optimizes the lands inside of the city (Seif Aldini et al., 2012). Compact city approaches define as; to increase built area and residential population densities; to intensify urban economic, social and cultural activities and to manipulate urban size, form and structure in pursuit of the environmental and social sustainability benefits (Jenks and Burgess, 2004). There are numerous viewpoints on concept of compact city that majority of theorists agree on concentrated development (Tsai, 2005) (Table 2).

Horizontal and vertical development is a relative concept, in the real world the urban development is not purely horizontal or vertical and the combined form of urban development is close to reality (Hatami Nezhad et al., 2012). The physical-spatial development is a complex system of physical, economic, social and environmental aspects. This type of development occurs due to different parameters such as distance from centers and workplaces and residential areas, access to communication networks, population density, land use zoning status, infrastructure development, the ratio of urban lands to undeveloped lands in neighboring areas, topography and natural disasters and economic factors (ownership rate, lease,

per capita income, employment rate, poverty, etc.). Table 3 describes the factors affecting the physical-spatial urban development from the perspective of experts.

Cities must develop physically and spatially to accommodate the population increase therefore, the physical-spatial development is influenced by the changes, distribution and density of population. As a result of population increase, changes occur in the use of urban land and surrounding areas in order to meet the population’s needs. Urban development is a complicated dynamic process, which involves various physical, social and economic factors. As a result, modeling an urban development pattern is the prerequisite to understand the process (Jianquan and Masser, 2001). Urban simulation, since its inception in the 1950s, was enabled and stimulated by developments in digital computing. The influence of the computer, moreover, was both direct and indirect through the role that digital computing played in making possible the present scope of statistical and other methods used in research (e.g., mathematical programming) (Páez and Scott, 2004). There are plentiful models using different indicators, however, Holdren entropy model has been justly considered to identify the pattern of the city. Spatial analysis techniques are applied in many research namely urban planning, Sociology, geography, environmental science et cetera. In academic term, spatial analysis is defined as an application of the quantitative methods in the study of point, line and surface patterns on

### Investigation of spatial-physical development model

Table 2: Compact city characteristics

Theorists	characteristics
Bibri and Krogstie (2020)	As a desirable form, the compact city indeed secures a development that is environmentally sound, economically viable, and socially beneficial
Knudsen (2018)	Compact city has gained prominence, as it represents an alliance between ecological and economic perspectives
Westerink <i>et al.</i> (2013)	Compact city emphasizes urban form as a determining factor in shaping sustainable societies and adheres to concrete growth boundaries to curtail sprawl
Holden and Norland (2005)	High-density development which happens inside or in the vicinity of urban center with combination of residential and business uses and workplace centers
Burton (2000)	High density, divers uses and proper public transportation which encourages citizen to walk and cycle
Williams <i>et al.</i> (2000)	A city with increased population and density in conjunction with investment in public transportation
Breheny (1995)	High density, a city with various uses where growth occurs inside the urban boundaries
Elkin <i>et al.</i> (1991)	A vertical city with an appropriate form and size for walking, cycling, public transportation and density that encourage social interactions.
Newman and Kenworthy (1989)	More use of land use, concentrated activity and higher density
Le Corbusier (1925)	A city with extremely high density (30000 N/H) where official buildings cover only 5% of the area and surrounded by wide open spaces and residential apartments encompass the official buildings

Table 3: Factors affecting the physical-spatial urban development

Experts	Factors of physical-spatial urban development
Bibri <i>et al.</i> (2020)	Population density, Land use zoning status, Access to communication networks and sustainable transportation.
Mahamud <i>et al.</i> (2016)	Distance from public amenities and workplace, Cheap housing price, Economic factors
Li <i>et al.</i> (2013)	Access to communication networks, Economic factors
Poelmans and Van Rompaey (2010)	Distance from centers and workplaces, Access to communication networks, Land use zoning status, Topography and natural disasters, Economic factors
Huang <i>et al.</i> (2009)	Distance from centers and workplaces and residential areas, Access to communication networks, Population density, Land use zoning status, Topography and natural disasters
Batisani and Yarnal (2009)	Access to communication networks, Population density, Land use zoning status, Infrastructure development, Topography and natural disasters
Shamsaini and Yaakup (2007)	Population density, Land use zoning status, infrastructure development, Topography and natural disasters
Hu and Lo (2007)	Distance from centers and workplaces, Access to communication networks, Ratio of urban lands to undeveloped lands in neighboring areas, Topography and natural disasters, Economic factors
Braimoha and Onishi, (2007)	Distance from centers and workplaces, Access to communication networks
Verburg <i>et al.</i> (2004)	Ratio of urban lands to undeveloped lands in neighboring areas
Šliužas (2004)	Topography and natural disasters, Population density, Economic factors
Cheng (2003)	Distance from centers and workplaces, Access to communication networks
Barredo <i>et al.</i> (2003)	Distance from residential areas, Population density

a map. In other words, it means the dexterity of cartography and statistical methods which help to process and analyze the spatial data and a description of the spatial pattern (Momeni and Mostafavi, 2019). At first, Iran's cities experienced organic growth and slight physical development (Seif Aldini *et al.*,

2012), however the ongoing rise of growth of the cities affected by the population increase and urban migration has led to unplanned constructions and many changes in the spatial structure of cities in the recent decades. The addition of oil revenue to urban economy, the physical growth and constructions



based on land trade (not on demand) (Majedi, 1999) spark off disordered urban land market, the disused part of lands inside the city, the horizontal expansion of cities (Athari, 2000), the destruction of rural agricultural lands as well as the development of informal settlements which entail paying heed to physical-spatial growth pattern of the city and directing the urban development wisely in order to prevent the loss of lands around the cities, especially in metropolises. Mashhad is known as the center of Khorasan Razavi province and the second largest metropolis of Iran. Initially, Mashhad's development was confined to the surrounding area of the shrine of Imam Reza in the shape of a star then it expanded to the west in a chess-shaped form. After the revolution, rapid population increase and immigrants have unbalanced the ratio between population and the physical growth of the city (Farnhad Consultancy Engineers, 2011). By comparing the ratios, it seems like the city has grown too horizontal. This paper focuses on the spatial analyses and Holdren entropy model to study the pattern of physical-spatial development of Mashhad during the previous decades (from 1986 to 2016). Accordingly, the following questions have been raised as the core of this study:

1. Is there any spatial autocorrelation of population in Mashhad?
2. How is the physical-spatial pattern of Mashhad? Which of the factors (population or horizontal expansion) have the strong influence of the city growth?

According to questions raised, the research hypotheses are as follows:

The conditions of spatial physical development of Mashhad city show that the population lacks spatial autocorrelation and a sprawl pattern. Also, the city growth is more influenced by population however, the impact of that on the development of the city will reduce gradually.

#### Literature Review

The previous studies and research related to this paper are described as below:

Yang *et al.* (2021) carried out a study on the spatial distribution pattern of Pro-Poor Tourism (PPT) villages in China. In their study, the spatial autocorrelation of 22651 pro-poor tourism villages was calculated using Moran's I. The outcome demonstrated that the spatial distribution of villages was roughly divided by the Hu

line, likewise there was an uneven agglomeration pattern of villages which was dense in the southeast and sparse in the northwest with six high-density core areas. Khodadad Bonab (2020) studied the pattern of spatial and physical growth of the Gorgan City in Iran using spatial statistics on GIS. The indicators including population, employment and density through different methods of spatial statistics namely cluster analysis, Moran and Gary Coefficients, general G and hotspots analysis were applied. The results indicated that Gorgan had a random spatial pattern with two hotspots located in the east and the south as well as one cold spot in the north. Abdi Torbeqan *et al.* (2019) investigated the physical pattern of the Kashmar City in Iran during 20 years using Shannon-Holdren entropy models and Moran coefficient. Their studies resulted in sprawl and disperse pattern of the city. Moran's I of population, household, residential unit and density represented cluster distribution and abnormal distribution of variables in the city. According to Koprowska *et al.* (2019) green spaces could act as a driving force affecting on housing demand and triggering city sprawl therefore, they assessed the linkages between urban sprawl and green space availability within the Lodz City in Poland. In this research, the city was divided into three zones. Urban Green Spaces (UGS) availability (especially forest and park) is one of the significant factors of housing development on the periphery of the city likewise, hotspots show the high density around the green spaces. By moving from the peripheral zone to center, UGS availability diminished as a result, the cold spots emerged showing the low residential density. Therefore, the rise of UGS availability in the peripheral zone of the city was connected to city sprawl. Cheng *et al.* (2019) applied three tools such as time-space cube, spatial autocorrelation, and hotspot analysis for exploring the traffic crash characteristics and identifying crash hotspots. The results illustrated that the traffic crash hotspots of road intersections were mainly distributed in the Northeast of Wujiang's urban area in China, while the crash cold spots were concentrated in the Southwest of Wujiang indicating low density of crashes at intersections. Hatami Nejad *et al.* (2017) analyzed the physical pattern of Khorramabad City in Iran using Shannon and Holdren entropy models. The findings represented that 24% and 76% of Khorramabad's growth originated from population and sprawl pattern respectively from

1989 to 2011. Newman and Kim (2017) conducted research on the spatial distribution of Non-productive Spaces (NPSs) of the city of Fort Worth in USA using GIS spatial analysis and directional distribution. The study aims to analyze the influence of NPSs on the fragmented urban core despite the growth of population and economy. Vacant land distributions were concentrated primarily on the eastern side of the city from 1990 to 2000, although they drastically relocated back to the center of the city for years afterwards, also hotspots analysis visualized the shifted direction. Parcel size and regeneration potential in the city center also decreased and resulted in a fragmented urban core by disconnected and irregularly shaped parcels of NPSs which are difficult to regenerate. Khakpoor *et al.* (2016) studied influential factors on unbalanced physical growth of Rasht City in Iran using Holdren model and GIS between 1976 and 2006. The results showed that 57% and 43% of the city's growth stemmed from population and sprawl sequentially. Also, the contradiction between status quo and current plans and approved detailed ones played a role in the unbalanced development of the Rasht City. Sahneh *et al.* (2015) used spatial statistics methods such as cluster analysis, Moran and Gary Coefficients, general G and hotspot analysis to examine the spatial growth pattern of Aq-Qala City in Golestan (Iran) and the findings showed that the pattern of population and employment was randomly scattered. The current study has been carried out in Mashhad in 2021.

## MATERIALS AND METHODS

This study falls into the category of quantitative researches and in terms of purpose, it is practical. The research method is descriptive-analytical one and data collection methods are based on library and documents. Due to the fact that generated maps using layers of census blocks produce massive quantities of data, techniques of exploration of information such as data mining seem suitable for spatial data such as urban development maps (Regin *et al.*, 2021). Spatial statistics are a set of exploratory techniques for describing and modeling spatial distributions, patterns, processes, and relationships. In other words, they include statistical methods so that integrates space and spatial relationships into the mathematical calculations (Pimpler, 2017). Spatial statistics help to understand the behavior of geographical phenomena

(Asgari, 2011). Understanding the behavior of urban dynamics with the insights of the region's carrying capacity would aid in evolving appropriate strategies towards the design of sustainable cities and estimating resources necessary for the future population (Aithal and Ramachandra, 2020). The statistical analysis tools used to study the pattern and trend of data, mainly seek to find the answer to the question of whether the distribution of the studied geographical features occurred arbitrary or experienced a particular trend (Asgari, 2011). Consequently, data analysis has been carried out using Holdren model and spatial statistics analyses such as Moran coefficient, hotspot analysis and directional distribution on ArcGIS Pro software. Holdren model identifies the urban sprawl growth (Hekmatnia and Mousavi, 2017). The model shows what percentage of the city growth originates from population and urban sprawl. The Moran's index measures spatial autocorrelation for a series of distances (Pimpler, 2017) and this Coefficient is used to evaluate the sprawl pattern of urban population. Hotspot analysis illustrates the scattering patterns of features and their characteristics on a map. Moreover, hotspot detection evolved from the study of point distributions or spatial arrangements of points in a space (Chakravorty, 1995). To identify the high population (high density) and low population (low density) in a city, hotspot and cold spot analysis have been applied. Directional distribution indicates that whether the distribution of geographical features in space is directional or not. Therefore, calculating the variances of the x and y axes precisely and independently, the distribution of phenomena in space can be represented. Applying this tool shows the direction of population in research (Asgari, 2011).

## RESULTS AND DISCUSSION

The city of Mashhad located in the northeast of Iran (Fig. 1), it has been described as a regional city and in some cases with national function in the approved documents. The initial core of Mashhad was gradually constituted of integration of three centers, namely Noghan City, the village of Sanabad and the holy shrine of Imam Reza. After the development of street networks during the period of First Pahlavi and social and economic transformations originated from World War II, the development of Mashhad accelerated swiftly in 1941s. Before 1976, Mashhad developed initially surrounding area of

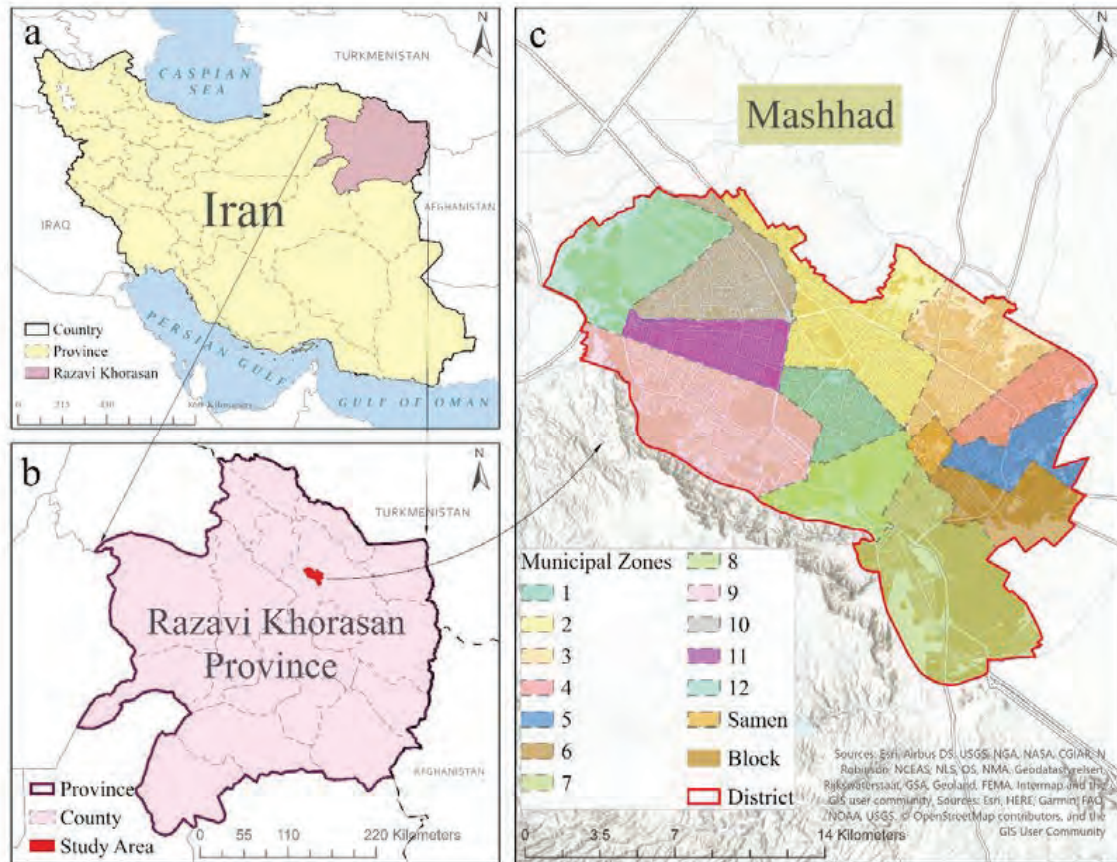


Fig. 1: Map of the study area. (a) Iran, (b) Razavi Khorasan province, (c) Mashhad

the shrine of Imam Reza in the shape of a star and the limit of the development was confined to Azadi highway. Afterwards with expansion to the west and development towards the western areas of Azadi highway, the development transformed to a chess-shaped form and Vakil Abad highway was the spatial axis of that. As a result of an increase in the number of migrants and pilgrims owing to expansion of transportation facilities and offering up-to-date services in the surrounding geographical areas as well as changes in construction which imbalance the corresponding between population and the physical extent of the city (Farnhad Consultancy Engineers, 2011). The purpose of current study is analyzing the physical-spatial pattern which has been carried out in the city of Mashhad (Iran) between 1986 and 2016. The research results help to grasp the population pattern and the city development of Mashhad better, so they are practical to monitor and manage urban

development, which are integral for urban planners and managers. The population of Mashhad was equal to 1463500 and 3001184 million people in 1986 and 2016 respectively (Management and Planning Organization of Khorasan Razavi Province, 2017) and it doubled during 30 years. The percentage of urbanization was approximately 43% and 89% in 1986 and 2016 sequentially. The area of the city went up by almost 166 times during the period indicating that as well as rapid growth of urban population, the area of that developed significantly. Therefore, Mashhad City faces the sprawl, unplanned and rapid development currently and does not proceed with the particular physical pattern. This kind of development has consequences namely, improper use of land (building constructions), loss of agricultural lands, imbalance in population distribution, inequality between resources and population, imbalance between population and economic activities, air pollution and water crisis.



Table 4: Moran's Index results of Mashhad

Year	1986	1996	2006	2016
Moran's Index	0.13	0.14	0.15	0.15
z-score	108.04	125.57	146.37	168.08

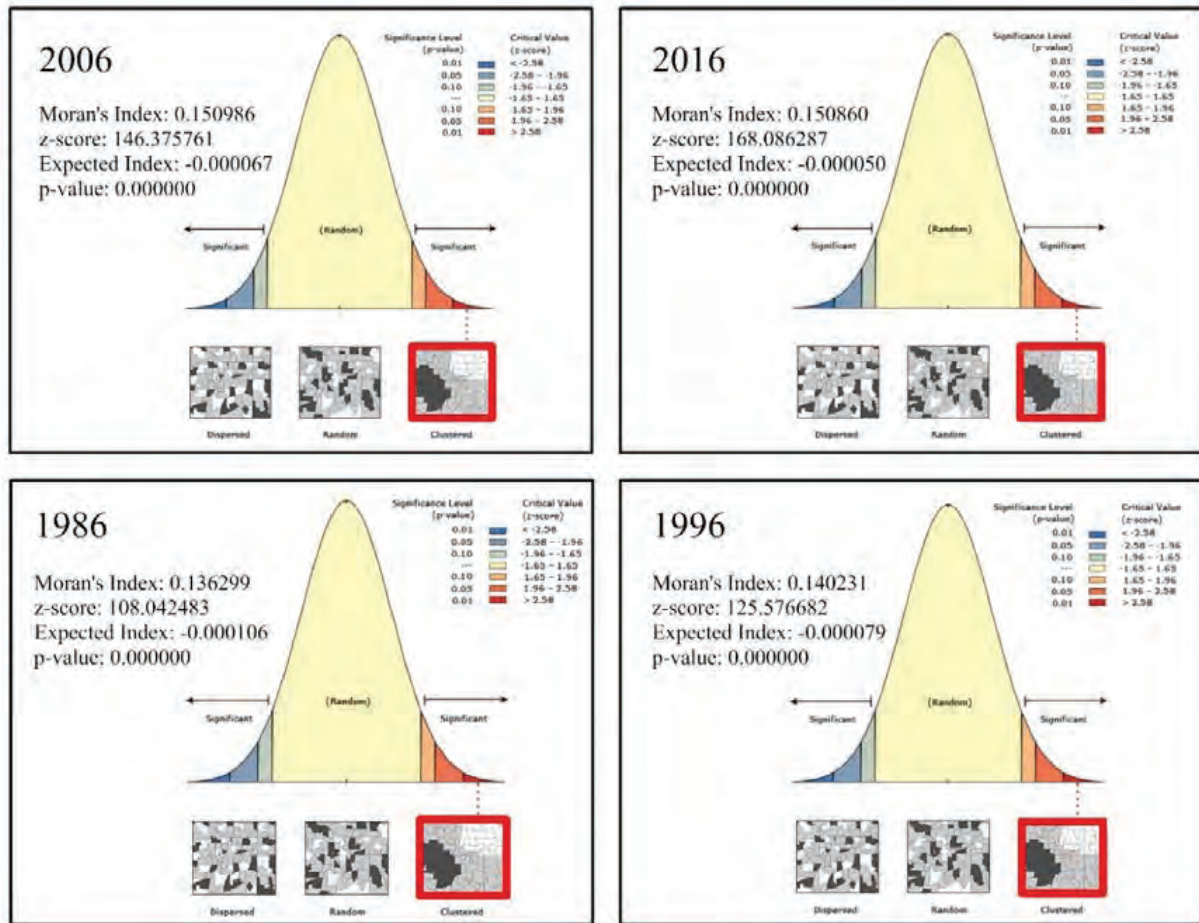


Fig. 2: Spatial autocorrelation reports

The analyses which have been carried out on the data of census blocks of Mashhad between 1986 and 2016 are describes as below; Moran's Index can be calculated as Eq.1 (Lee and Shengwen, 2016) where  $n$  is defined as the number of census blocks,  $a$ , is population,  $w$  is the spatial weight of census block in this case. The Moran coefficient ranges from +1 to -1 which a high positive value indicates clustering as well as high density (Tsai, 2005). In this case, according to Table 4, The Moran's Index values obtained from 1986 to 2016 are positive and greater than zero but the values cannot be scrutinized in isolation, therefore

the z-score and p-value must be factored in which are defined as Eqs. 2, 3 and 4 (Asgari, 2011) so that the larger the z-score is the more intense the clustering. In view of positive values of Moran's index, high z-score (Table 4) and the low p-value, the correctness of the first hypothesis has been examined and the basic assumption of spatial randomness are rejected. In other words, the population pattern of Mashhad is clustered and continuous in some parts and is not dispersed through the city. Therefore, it is concluded that the population of different segments of the city has a spatial autocorrelation during 10-year intervals.

If population was scattered in 2016, the Moran's I would be negative value of 0.000050 (Fig. 2).

$$I = \frac{n \sum_{i=1}^n \sum_{j=1}^n w_{ij} (a_i - \bar{a})(a_j - \bar{a})}{\sum_{i=1}^n \sum_{j=1}^n w_{ij} \sum_{i=1}^n (a_i - \bar{a})(a_i - \bar{a})} \quad (1)$$

$$Z_i = \frac{I - E[I]}{\sqrt{V[I]}} \quad (2)$$

Where:

$$E[I] = -I / (n - 1) \quad (3)$$

$$V[I] = E[I^2] - E[I]^2 \quad (4)$$

The Getis-Ord  $G_i$  statistic for each feature in a dataset is calculated by the Hot Spot Analysis tool which is derived from the Eqs. 5, 6 and 7. Where  $x_j$  is the population of feature  $j$  and  $w_{ij}$  is the spatial weight between features  $i$  and  $j$  (census blocks) and  $n$  is the total number of census blocks in each year. The  $G_i$  statistic is also known as a z-score. For statistically significant positive z-scores, the larger the z-score is, the more intense the clustering of high values (hot spot) and vice versa (Esri, 2014). Table 5 represents the minimum and maximum of the calculated  $G_i$  for each year. The maximum values of  $G_i$  increased over time indicating that the number of clusters and hot spots was heightened. In 1986, the hotspots of population were in the northeast region (neighborhoods of Isar, Tolab, Resalat, ...), afterwards in 1996, the hotspots did not develop significantly, only one hotspot appeared in the northwest of Mashhad (Azadshahr and Zibashahr neighborhoods), however, the number of hotspots increased and scattered in 2006, so that in 2016, these spots were located in a contiguous area from east to northwest

and west reflecting high population concentration (Fig. 3). In view of spreading hotspots, it is concluded that the large part of population density is made up of Informal Settlements and worn-out urban textures (neighborhoods of khatam Alanbiya, Imam Hadi, ...) and the west part of the city affords optimal housing and appropriate access to services accordingly, the accessibility to main roads (vakil Ababd highway, Toos boulevard and 100-meter ring road) plays a prominent role in housing. Cold spots or places with low population densities are located in the city center and northwest, which have the potential to accommodate future populations. Recognizing these spots offers an opportunity for urban planners to adopt a decision of service allocation which leads to improvement of city functionality.

$$G_i = \frac{\sum_{j=1}^n w_{ij} x_j - \bar{x} \sum_{j=1}^n w_{ij}}{S \sqrt{\frac{n \sum_{j=1}^n w_{ij}^2 - \left( \sum_{j=1}^n w_{ij} \right)^2}{n - 1}}} \quad (5)$$

$$\bar{x} = \frac{\sum_{j=1}^n x_j}{n} \quad (6)$$

$$S = \sqrt{\frac{\sum_{j=1}^n x_j^2}{n} - \bar{x}^2} \quad (7)$$

The Standard Deviational Ellipse tool created a new Output Feature Class containing elliptical polygons, one for each census block. The attribute values for these ellipse polygons include  $x$  and  $y$  coordinates for the mean center, two standard distances (long and short axes according to Eq. 8 and Eq. 9), and the orientation of the ellipse (Eqs. 10, 11, 12 and 13) (Esri, 2014) (Asgari, 2011). According to standard deviational ellipse, the developed distance along the  $X$  axis started at 5959.39 in 1986 and reached 9119.12 in 2016 and the expansion along the

Table 5: The calculated values of  $G_i$  statistic for each census block of Mashhad

Year	Gi (Z score)	
	Min	Max
1986	- 8.95	14.89
1996	- 11.73	17.71
2006	- 12.41	19.72
2016	- 12.30	14.46



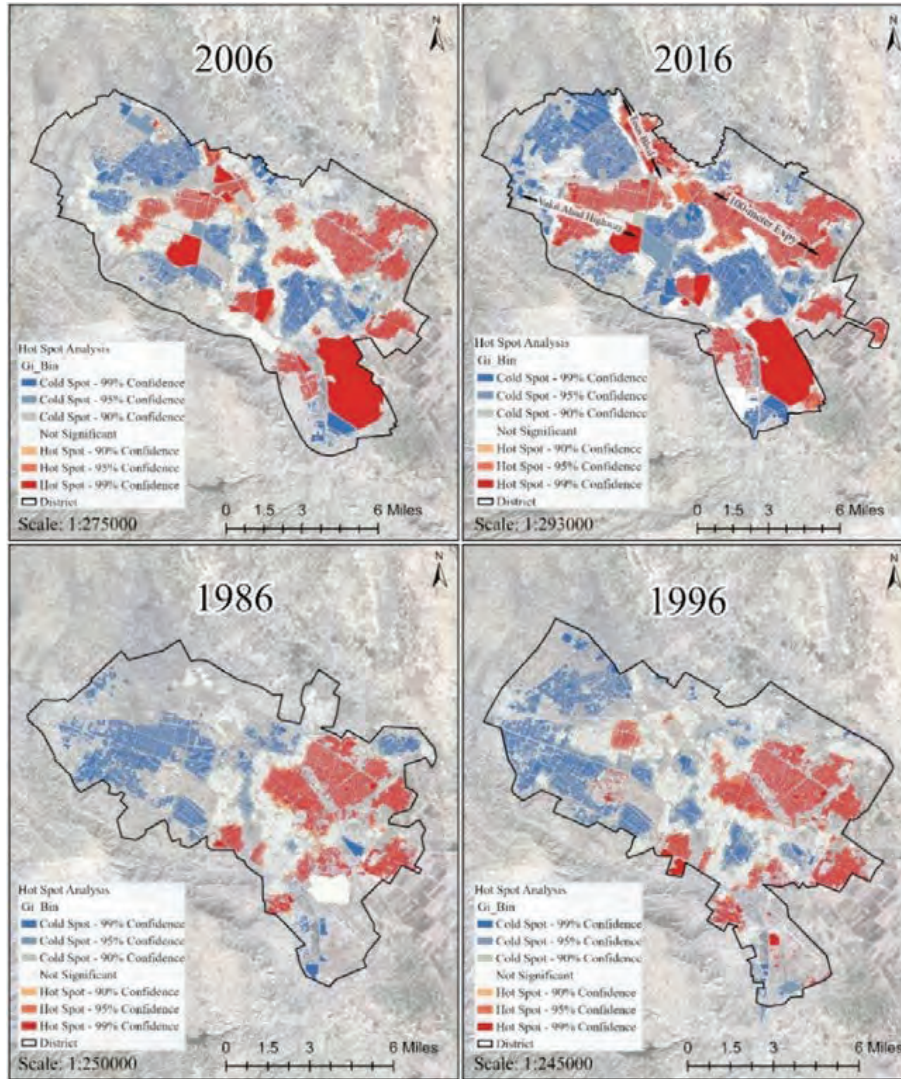


Fig. 3: Hotspot analysis output on the census block showing clustering of population

Y axis went up by 921.76. As a result, through time, Mashhad expanded through both axes with rotation of 0.16 radian between 1986 and 2016, although the expansion along the X axis is more considerable in comparison to Y axis (Table 6). The rotation degree depicts that population ellipse has revolved clockwise across the X axis. In other words, the location of studied feature (population) has altered across the X axis. Consequently, the diffusion of population is heading to the northwest.

$$SDE_x = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{X})^2}{n}} \quad (8)$$

$$SDE_y = \sqrt{\frac{\sum_{i=1}^n (y_i - \bar{Y})^2}{n}} \quad (9)$$

$$\tan \theta = \frac{A+B}{C} \quad (10)$$

Table 6: Directional distribution results

Year	1986	1996	2006	2016
X standard distance	5959.39	7589.24	8300.99	9119.12
Y standard distance	3699.03	3939.04	4258.83	4620.79
Rotation ( $\tan \theta$ ) (rad)	1.87	1.94	1.94	2.03

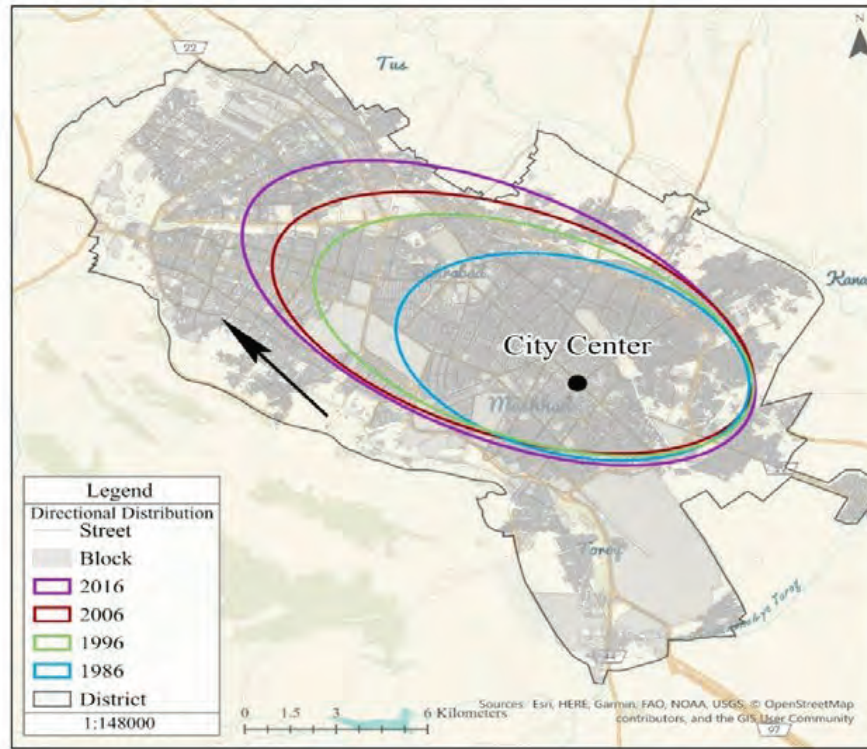


Fig. 4: Directional distribution output showing population patterns in studied years

$$A = \sum_{i=1}^n \tilde{x}_i^2 - \sum_{i=1}^n \tilde{y}_i^2 \quad (11)$$

$$B = \sqrt{\left(\sum_{i=1}^n \tilde{x}_i^2 - \sum_{i=1}^n \tilde{y}_i^2\right)^2 + 4\left(\sum_{i=1}^n \tilde{x}_i \tilde{y}_i\right)^2} \quad (12)$$

$$C = 2 \sum_{i=1}^n \tilde{x}_i \tilde{y}_i \quad (13)$$

Table 7 indicates a moderately rising trend in the population of Mashhad from 1463500 to 3001184 people in 1986 and 2016 successively. Considering the reduction in per capita and upward trend in Gross

urban density, it is apparent that the population growth outweighs the increase in urban area. According to the Holdren model (Eq. 14) (Hekmatnia and Mousavi, 2017), the natural logarithm of population remained stable at 0.25% in the first twenty years beginning from 1986 however after a slight drop in 2006 it reached 0.28% in 2016. The calculated natural logarithm of per capita shows a slight growth by 0.18% during studied years. The sum of natural logarithm of population and per capita demonstrates the natural logarithm of urban area which started with 0.35% in 1986 and finished with 0.54% in 2016. The entropy values obtained were 74% of population growth and 26% of dispersed growth in 1986, which reached 51% and 49% respectively in 2016. Generally

Table 7: Basic statistics of Holdren entropy model

Year	Population	Per Capita	Gross urban density	Urban area (m <sup>2</sup> )
1986	1463500	126	79	185 000 000
1996	1887400	138	72	261 000 000
2006	2427300	122	81	300 000 000
2016	3001184	103	97	307 900 000

Table 8: The calculations of Holdren entropy model

Year	Ln (Population)	Ln (Per Capita)	Ln (Area)	Population Growth	City Sprawl
1986	0.25	0.09	0.35	74%	26%
1996	0.25	0.12	0.37	67%	33%
2006	0.21	0.17	0.38	56%	44%
2016	0.28	0.27	0.54	51%	49%

Table 9: The comparison between annual growth rate of population and urban area

Period	Annual population growth rate	Annual growth rate of the urban area
1986-1996	2.58 %	3.5 %
1996-2006	2.54 %	1.4 %
2006-2016	2.14 %	0.3 %

speaking, the large segment of Mashhad's growth resulted from population, despite the fact that the rate of city sprawl went up gradually. To be specific, the percentage of population growth decreased by 23% which added to urban sprawl (Table 8). This trend will lead to unplanned and disperse growth, reduction of gross urban density and an increase in per capita in the not-so-distant future. From 1986 to 2016, not only did the annual population growth rate fall by roughly 0.45% but also the annual growth rate of the urban area slumped sharply by 3.2% (Table 9). Considering the gradual decrease in annual population growth rate during studied periods, it is self-evident that population will have minor influence on Mashhad's growth and its development. Also, the annual growth rate of Mashhad's area sharply slumped and considering reduction in population growth rate, it is derived that the increased ratio of the city area has been added to rate of city sprawl.

$$\ln\left(\frac{\text{population of end period}}{\text{population of start period}}\right) + \ln\left(\frac{\text{per capita of end period}}{\text{per capita of start period}}\right) = \ln\left(\frac{\text{urban area of end period}}{\text{urban area of start period}}\right) \quad (14)$$

Comparing the analyses, Mashhad City confronts unscheduled growth which confirms the hypothesis about a sprawl pattern. Spatial autocorrelation of population and its clusters can be observed more in the east to northwest area which might result from low dwelling prices and the vicinity of 100-meter ring road. Therefore, this area mainly includes fine-grained residential areas and informal settlements which are located among agricultural farms. Likewise, the standard deviation ellipse of population is the embodiment of horizontal development. In view of the locations of cold spots, there is an opportunity for Endogenous development and compaction mainly in the northwest zone. Also, the existence of cold spots in the city center (around the shrine) shows a chance for interior development however in status quo, high-rise buildings and uses related to tourism and hospitality such as hotel and small business associated to shrine are placed there. Moreover, illegible urban context, low permeability of this area to Checkered texture of the northwest, the heavy traffic during rush hours and crowds of pilgrims have made it difficult for physical intervention and inner development in the zone. The main difference between the current research and the conducted studies in the literature review such as Yang *et al.* (2021), Khodadad Bonab (2020), Abdi Torbeqan *et al.* (2019), Cheng *et al.* (2019) and Newman and Kim (2017) is that the directional

distribution as well as Moran coefficient and hotspot analysis have been applied, simultaneously. Moreover, the spatial statistics analyzes have been surveyed in a long-term period (30 years). The results of spatial statistics tools and Holdren model are consistent and show the horizontal growth with a random and scattered pattern representing high density of population clusters. Which is similar to the one of conducted studies in other Iranian cities which were previously mentioned in the literature review such as the study of [Khodadad Bonab \(2020\)](#), [Abdi Torbeqan et al. \(2019\)](#), [Koprowska et al. \(2019\)](#) and [Sahneh et al. \(2015\)](#). Also, based on the results of the Holdren model, it has been determined that the expansion of Mashhad, like other major cities in Iran, is more affected by population growth and the final hypothesis is confirmed. survey of the directional distribution and the location of hot spots show that proper access and the existence of highway networks are the main factors in the spread of Mashhad. Although many areas of development are located around agricultural lands, it could not be reconciled with the study of [Koprowska et al. \(2019\)](#), who consider green spaces as the main factor in urban development. Because these areas are informal and poor settlements that have invaded the agricultural lands around the city. Therefore, it can be concluded that among the factors affecting the physical-spatial urban development ([Table 3](#)), the physical-spatial development of Mashhad is more affected by access to communication networks, population density and economic factors.

## CONCLUSION

The analysis of the development of Mashhad has been carried out using spatial statistics analyses and Holdren model during previous decades (from 1986 to 2016). Taking the positive values of Moran coefficient into consideration, it comes to the conclusion that the population of Mashhad is clustered and there is spatial autocorrelation. Consequently, the population accommodation has accumulated to some particular locations over time, in other words, it is not homogeneously distributed and it is moving to the northwest. Likewise, the obtained hotspot analyses obviously represent the dense population from the east to the northwest. The analysis of population direction using standard deviational ellipse reveals that the distribution of population has a direction

in urban space and population is proceeding to the northwest from a certain point. The values of Holdren model indicate that population has a profound impact on the development of Mashhad from 1986 to 2016 successively but due to reduction in the percentage of growth stemmed from population and the rise in percentage of city sprawl, the percentage of city sprawl will exceed the population and act as a dominant factor on the development of the city for the foreseeable future. Hence, Mashhad which is recognized as the second most populous metropolis, faced a horizontal pattern during 30 years, on the other hand owing to natural barriers such as southern and southwestern heights, plenty of agricultural lands in the east, Kashafrud River and Binaloud County in the north and west sequentially, proceeding according to this pattern has culminated in encroachment of physical-spatial development to fertile agricultural lands and reduction in groundwater aquifers as well as disruption to the ecological order. Based on the results of this study, the following suggestions are put forward to improve the planning of the Mashhad's development:

- The control of the migration rate from rural to urban areas;
- Governing and maintaining the legal city limit;
- Inner city development (allocation of capital to the development of areas with low population density);
- Invention of proper building regulations and prevention of unplanned and non-standard constructions;
- Lending support to Energy efficient constructions;
- Adjust residential densities based on environmental compatibility;
- Expansion of public welfare amenities, health, educational and ... facilities in the city;
- Reduction in commuting from workplace to residence and leisure facilities;
- Improvement and development of public transportation network corresponding with population;
- Implementing Incentive policies to make citizens use more public transportation;
- Adopting appropriate policies to address issues such as traffic congestion in areas with high population density (monitoring the rise of building density, Widening streets, ...).



## AUTHOR CONTRIBUTIONS

M. Jahanbani helped in the research method and performed the literature review and compiled the data as well as generating maps, the manuscript preparation, analyzing and interpreting the data, preparing the manuscript text and manuscript edition. E. Lashkari was the mentor and performed the introduction and research method, helped in preparing manuscript and its edition as well as interpreting the data and proposed constructive comments.

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## CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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## ABBREVIATIONS

$\bar{a}$	is the mean of all a
$a_i$	the attribute value of geographic object i
$a_j$	the attribute value of geographic object j
Eq.	Equation
$G_i$	Getis-Ord statistic
$I$	index
$\ln$	Natural logarithm
$m^2$	Square meters
$n$	the number of geographic phenomena
NPS	Non-productive Space
PPT	Pro-poor Tourism
$p$ -value	Probability value
rad	radian
SDE	Standard deviational ellipse
$\tan \theta$	Orientation of the ellipse
UGS	Urban Green Space
$w_{ij}$	a weight defined for events i and j (spatial weights)
$x$	coordinates for the mean center
$x_j$	the population of feature j
$y$	coordinates for the mean center
$z$	z-score

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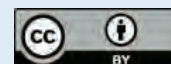


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ORIGINAL RESEARCH PAPER

The relationship between technology and economic growth: The moderating role of human capital

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ABSTRACT

**BACKGROUND AND OBJECTIVES:** Most economists believe that the lack of investment in manpower is the cause of low economic growth in developing countries, and as long as these countries do not use their knowledge to improve their professional skills, the return on labor and capital will remain at a low level. This study was designed to evaluate the impact of human capital on the relationship between technological advances and economic growth in Southwest Asia within 2000 and 2018. For this purpose, the growth of internet economy in the world and the development of education for strengthening the human capital and its effect on the world economic growth were studied.

**METHODS:** The technological advances were assessed using two Components of the number of... internet users ...and the number of mobile subscribers. The scope of this research is from 2000 to 2018. The Generalized Movement Method and the EViews 10.0 software were used to test the research hypothesis through model.

**FINDINGS:** The first model showed that the significant effect of human capital on the relationship between internet and economic growth. In this model, the internet coefficient was equal to 0.357, implying that the economic growth in the studied countries would increase at a rate of 0.0357 units with the increase of the internet coefficient by one unit. Moreover, the human capital coefficient was equal to 0.0618, implying that the economic growth in the intended countries would be improve by 0.06 units with the increase of the human capital coefficient by one unit. The second model revealed the significant relationship between mobile phones and economic growth in the countries with a higher human capital involving the educated employed people. This was consistent with the results of self-correlation of fixed effects.

**CONCLUSION:** According to the results, it was concluded that human capital would moderate the relationship between internet and economic growth. Moreover, it was confirmed that the effect of education on the relationship between mobile phones and economic growth was significant.

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## INTRODUCTION

Nowadays, human capital is considered as an undeniable factor in the development of countries. Since human capital is deemed as a prerequisite for development, the speed and pace of development are dependent on the quantity and quality of efficient human resources. The effect of human capital on economic growth can be explained from many aspects. Assuming that other conditions are stable, investing in human resources may increase the productivity of individuals. Analyses suggest that this investment can lead to rise in production through transfer of new technology and its application. Thus, higher levels of human capital in the realm of education would provide more necessary grounds for using imported technology (Barghandan *et al.*, 2011). Considering the role of technology in improving the training of human resources aimed at specializing tasks, internet has a potential to make economic activities more efficient and cheaper. It also broadens social interactions while accelerating economic activities. This process can also bring benefits in different forms by promoting the business efficiency obtained through the use of online networks. From a macroeconomic perspective, internet and related technologies reduce the cost of sending and receiving information and enhance both the level of total product and the efficiency of the whole economy. Thus, the expansion of internet has been recognized and introduced as an essential principle in economic development in a knowledge-based economy (Chaharband and Momeni, 2011). Grossman and Helpman (1991) considered the innovation and advances in existing products as drivers of economic growth. Today, most of the economists believe that the lack of investment in human capital is the main reason for low level of economic growth in developing countries, and since these countries do not use their knowledge to improve their professional skills, their returns, labor and capital efficiency would remain at a low level (Souri and Mehregan, 2007). Lucas (1988) examined the relationship between total product and solo growth model and put forward the idea that the level of human capital would directly affect the production. It is also assumed that human capital is produced by different technologies, in which the focus is on manpower training (Mehregan *et al.*, 2012). According to the theoretical foundations of economic growth, Information and Communications Technology (ICT), by improving productivity and reducing costs,

has a positive effect on economic growth (Amin Rashti *et al.*, 2014). In some countries many innovations have been introduced in national accounts in order to better gauge the ICT diffusion impact. This thesis discusses how the use of ICT contributes to economic growth, also provides an insight of results from past studies carried out to confirm the productive relationship between ICT and economic growth. Many papers use industry-level data set to quantify the role of ICT in explaining productivity growth but it isn't the only way for ICT to affect the economic. New ICT makes consumers better informed about available products, product quality and prices, which mitigates problems of asymmetric information, the entry of firms is facilitated, competition and economic efficiency is boosted and the market powers of households increased (Zandieye, 2014). Iran is known as a developing country which has not succeeded to make a significant contribution to the global economic growth due to struggling with many problems such as a low level of manpower productivity, absence of expertise required for production, and failure to export competitive goods. Thus, the economic growth improvement in Iran seems to depend on efficient training of human resources as the most important infrastructure for the promotion of technology. What matters most here, is the potential of human capital to serve as a valuable investment for dynamic economic growth, which in turn improves production functions (i.e., economic growth). The purpose of this study is to investigate the effect of the role of education on the relationship between technological advances and economic growth in Southwest Asia during the period 2000 to 2018. The present study aims to answer the question that "Does human capital moderates the relationship between technology indices and economic growth?"

### Research background

Shidong *et al.* (2022) in a study examined the moderating role of human capital and renewable energy in promoting economic development in G10 economies: Evidence from the CUP-FM and CUP-BC methods. Thus, this study explores the impact of human Capital, renewable energy, and the interaction of both in realizing higher economic development. For empirical analysis, comparatively new panel estimation techniques were employed including "continuously updated fully modified" (Cup-FM) and "continuously

updated bias-corrected" (Cup-BC) using a panel of G-10 countries. The overall results demonstrate that human Capital and renewable energy stimulate higher economic development. Manifestly, the interaction of both variables reports a more substantial impact on economic development, implying that human capital development is a stimulus to boost the positive effects of renewable energy sources on economic growth. Based on the findings, the stakeholders are recommended to invest in human Capital and renewable energy adoption. [Ficawoyi \(2018\)](#) examined the relationship among communication infrastructures, economic growth, and access to education. Economic growth, technology (internet users and mobile subscribers), and education were assumed as dependent, independent, and moderating variables, respectively. It was finally concluded that, compared to mobile phones, internet could contribute to economic growth in the countries with better access to education. [Samati et al. \(2015\)](#), by examining the effect of industrial accumulation and urbanization on economic growth in Iran, concluded that urban savings in both industrial and non-industrial provinces had a positive and significant effect on labor productivity. [Komijani and Mahmoudzadeh \(2008\)](#) discussed the role of information and communication technology in Iran's economic growth (growth accounting approach). This was accomplished among 30 provinces (obtained from various publications of the Statistics Center of Iran) to estimate the country model and the time period on the panel data. A cross-sectional estimation was carried out on the model equations via the two-stage least squares method (2SLS), and the results showed that focusing on education, as one of the indicators of human capital, had a positive effect on the country's economic growth. [Allmran and Allmran \(2017\)](#) in a study examined the impact of information and communication technology on the economic growth in Member Countries Department of D8. The method used in the research was causal-analytical. The econometric tools used in the research are Eviews software and the econometric method used in the research is the data panel method. Pakistan, Malaysia, Egypt and Nigeria. According to the research findings, the effect of coefficients of variables based on expected theoretical foundations is also statistically significant and information and communication technology has a positive and significant effect on economic growth in these countries. [Almasi and Sepahban Ghara Baba](#)

[\(2009\)](#) studied the relationship among investment in manpower, physical investment and economic growth in Iran during 1982-2012 and reached a two-way Granger causality relationship between economic growth and human capital in short and long terms. [Pourfaraj and Issazadeh Roshan \(2010\)](#) examined the relationship among ICT, income inequality and economic growth. It was found out that the dimension and scope of education and economic growth were very wide and only a small part of them was covered in experimental studies in Iran. [Afzal et al. \(2011\)](#) in a study explored the cointegration and causality between education and economic growth in Pakistan by using time series data on Real Gross Domestic Product (RGDP), labor force, physical capital and education from 1970-1971 to 2008-2009 were used. Autoregressive Distributed Lag (ARDL) Model of Cointegration and the Augmented Granger Causality Approach given by [Toda and Yamamoto \(1995\)](#) were applied. The findings of this study also indicate the existence of the feedback causality between education and all levels of education with economic growth. Among all levels of education, general higher education causes economic growth highly and most significantly while the level of confidence of causing economic growth to school education is found to be the highest. [Chachar and Hassan \(2013\)](#) studied the mobile phone usage among American farmers and showed that mobile phones could save energy and time of the farmers and ultimately improve their income. It was claimed that mobile phones provided the farmers with an opportunity to directly communicate with market brokers and customers in order to sell their product in good price. [Moshiri and Jahangard \(2004\)](#) examined the effect of investment in communications on Iran's economic growth using the state space method. It became evident that investment in communications had a positive and significant effect on economic growth in Iran. [Asari and Aghaei khondabi \(2008\)](#) estimated the empirical growth pattern of Organization of the Petroleum Exporting Member Countries (OPEC). The relationship between ICT and economic growth of the mentioned countries was also examined using the Cobb-Douglas production function obtained from the panel data method within 1998-2004. It was concluded that there was a strong relationship between ICT and economic growth. [Zhang and Zhuang \(2011\)](#) investigated the impact of human capital components on China's economic growth using the Generalized



Method of Moments (GMM) during 1998-2008 and used various data from different provinces of China and finally reported that the effect of education at university level on economic growth was greater than that of the primary and high school education. [Shahnazi \(2012\)](#) investigated the factors affecting the production of industries with superior technology in a knowledge-based economy (panel data approach by generalized least squares method). [Katircioglu \(2009\)](#) evaluated the relationship between higher education and economic growth using the annual data of Cyprus and the Granger causality test. He revealed an indirect causality relationship between higher education and economic growth in the long term. [Najarzadeh and Rahimzadeh \(2012\)](#) measured the impact level of internet on economic growth during 1995-2010. Their results revealed that internet access and per capita expenditure had a positive effect on the GDP growth per capita. [Mohammadzadeh et al. \(2015\)](#) studied the effect of creativity on economic development in Iran, aiming to explain the relationship among science development, technology development and economic growth. The results of their study indicated a two-way relationship among science development, technology development and economic growth. The results also show that economic growth and technology development were the most influential criteria in communication network, respectively. [Tayebi et al. \(2007\)](#) evaluated the effect of foreign trade and human capital on economic growth of the member countries of the Organization of the Islamic Conference. The results indicated the positive and significant effects of human capital growth on economic growth of the member countries of the organization during the study period. Another conclusion that can be stated is that the combined relationship of each trade variable with human capital could have a positive and significant effect on economic growth. [Salmani Bishak and Ashkan \(2014\)](#) studied the effect of the export of industrial goods on economic growth in Iran. Findings show that, contrary to exogenous productivity growth, human capital could be accumulated through investment (i.e., the individuals would choose how long to invest for education by themselves). [Naderi \(2014\)](#) attempted to evaluate the effects of general education and higher education on economic growth in Iran. He employed an endogenous growth model which had been developed using the data from 1959 to 2007. The results his study confirmed that the relationship

between accumulation of human capital and accumulation of physical capital had a positive and significant effect on Iran's economic growth in the long term. [Basir \(2014\)](#) studied the impact of the accumulation of physical, human, and social capitals on economic growth. [Kenny \(2003\)](#) analyzed the effect of internet on economic growth and asserted that internet was a powerful tool with a long-term effect on the quality of life in developing countries. In the present study, it was attempted to determine if human capital, social capital, and physical capital had a two-way relationship with economic growth or not. Then the effect of sudden shocks on economy and the reaction of the above-mentioned variables to these shocks were evaluated. Ultimately, the share of each variable on changing the other variables over time was calculated. Although many studies have investigated the impact of education and technology on Iran's economic growth so far, none of them has addressed the moderating role of human capital on the relationship between technology and economic growth. In this study, the number of employed people with university education was used as an alternative to human capital because: 1) these people were directly involved in the production process, and 2) the use of other indicators, such as government spending on education, could doubtfully lead to accurate results due to the large and growing number of the unemployed people with higher education. The current study has been carried out in Sabzevar in 2020.

## MATERIALS AND METHODS

### *Survey design and data collection*

This work is classified as an applied study on economic issues in terms of objective. The methodology used in this study is a descriptive approach of post-event type (using past information). It falls within the correlational research category concerning the content and nature. Normally, a correlational research includes all the studies where it is intended to discover or determine the relationship between different variables using the correlation coefficient. The unit root test (variability) of the data is the first test that researchers use in estimating the model. Mana data is considered to be that over the average time, the variance of that variable is equal during the same intervals. Various tests are used to determine the unit root test, which can be referred to Levin, Lin and Chow test ([Setayesh, 2015](#)) and Augmented Dickey-Fuller (ADF) test ([Paparoditis,](#)

and Politis, 2018). The hypothesis testing model in this study, which is developed based on Ficawoyi (2018), is as Eq. 1:

$$(1) \text{Growth}_{i,t} = \alpha + \vartheta_i + \phi_1 \text{Growth}_{i,t-1} + \phi_2 \text{Techni}_{i,t} + \phi_3 \text{h.capital}_{i,t} + \phi_4 (\text{Techni} * \text{H.Capital})_{i,t} + \text{Xi}'_i \beta + \varepsilon_{i,t}$$

Where, *Growth* refers to economic growth obtained through the calculation the logarithm of GDP of the selected countries at a fixed price in 2010; *Growth<sub>i,t-1</sub>* is the economic growth of the past period obtained by subtracting the economic growth of the last year from that of this year divided by the economic growth of the previous period (Lashkari 2009); *H. Capital* is the human capital variable measured using the number of employed people with academic education; *Techni* refers to the technology indices where two indices of number of internet users and number of mobile phones subscribers are used as technology measurement indicators; and *Xi* is the sum of controlling variables including: 1) Government which is the Government Consumption (GC) expenditure obtained from the ratio of final GC expenditure to GDP; 2) Investment which is obtained from the ratio of gross capital formation to GDP (Azarbayjani et al., 2009); 3) Inflation which is the rate of inflation obtained as the consumer price index (annual%) (Laspeyres price index) (Nowruzi, 2014); and 4) Openness to trade which the trade's openness obtained from the ratio of the sum of export and import of the intended country to its GDP (Dadgar and Najimeydani, 2003). The hypothesis followed in this study is as follows:

- Technology and economic growth have a significant relationship with the moderating role of human capital.

#### Data collection method

The data were collected from two library sources and the World Bank Indicators database. The library method was also utilized to collect the theoretical literature and concepts. The data on dependent variable (economic growth) and independent and control variables were extracted from the World Bank's World Development Indicators (WDI) website and then collected in Excel spreadsheets. These data were collected annually. The statistical population used in this study involved 25 countries located in the Southwest Asia. Considering the availability of the required data, 22 countries (Iran, Saudi Arabia, Kazakhstan, Pakistan, Turkey, Afghanistan, Yemen, Turkmenistan, Uzbekistan, Iraq,

Oman, Kyrgyzstan, Syria, Tajikistan, Jordan, Azerbaijan, UAE, Georgia, Armenia, Israel, Kuwait, Qatar, Lebanon, Cyprus, and Bahrain) were selected as the sample size. In collecting data related to testing hypotheses, in order to achieve the goals and ultimately answer the questions raised and the progress of this research, according to the developed model and variables studied from the World Bank Global Development Index and in some cases from Excel and Eviews 10.0 softwares were used.

#### Analytical framework

The Generalized Method of Moments (GMM) or dynamic panel data is known as an efficient econometric method which eliminates the endogeneity between dependent and explanatory variables using instrumental variables. The 2SLS econometric method has been used in many economic studies to resolve the endogeneity problem. However, this method requires finding a proper instrumental variable to solve the endogeneity problem of variables. The advantages of the Dynamic Panel Data (GMM) method are: 1) considering the individual differences and further information, and 2) eliminating the biases in cross-sectional regressions. These advantages lead to more accurate estimates with higher efficiency and less collinearity in the method (Ahmadi et al., 2016). Since in the research model, the dependent variable appears intermittently to the right of the equation, researcher is faced with a dynamic panel data pattern. In this study, Sargan test was used to evaluate the consistency of GMM estimators is. Eviews10.0 software is also used for statistical and econometric analysis. The co-integration method allows regression to be estimated based on time series variables without fear of being false. Numerous tests have been proposed to test co-integration with completely different approaches, including the Pedroni (2004) and Kao (1999) tests. The Cao test is based on the regression residual test and is similar to the parasite-granger co-integration test in time series data (Nourafshan and Jabbari Noghabi, 2012).

## RESULTS AND DISSCUSION

#### The model estimation

To examine the durability of the model variables, the unit root test was performed before estimating the model in order to avoid the estimation false regression. Accordingly, the unit root test was embedded for all

the variables included in Eviews 10.0 software and the results were obtained (Table 1).

The Levin-Lin-Chou test (Setayesh, 2015) is used to perform the unit root test. All the studied variables were found to be at a durability level in the Levin-Lin-Chou test, and thus, the probability of false variables seemed to be zero, which is mentioned in the analytical framework section.

#### Cointegration tests

The cointegration test was conducted before estimating the model to avoid false regression (Table 2). Among the two tests (Kao, Pedroni) which have been developed to test the cointegration, the Kao test was selected to be used in this study. This test is mentioned in the Analytical Framework section.

According to the results, the establishment of cointegration in the model was accepted due to the Augmented Dickey-Fuller (ADF) (Paparoditis and Politis, 2018). statistic and its relevant probability. In other words, the null hypothesis of the model (the absence of cointegration) was rejected. Therefore, a long-term relationship could be noticed between the dependent variable and the independent variables. According to Table 3, the models (the first and the second models) were estimated using the Generalized Method of Moments. The technology indices (the

number of internet users and the number of mobile phones subscribers) showed a positive and significant impact on economic growth in these models. In the first model, human capital had a significant effect on the relationship between internet and economic growth. In other words, the internet user coefficient of 0.357 implied that if this coefficient increased by one unit, the rate of economic growth in the studied countries would increase at a rate of 0.0357 unit. In other words, this hypothesis is confirmed that there is a significant relationship between the number of Internet users and economic growth at the level of 5%. in fact, confirmed the hypothesis of the present study. This was also consistent with the findings of Ficawoyi (2018) and Najarzadeh and Rahimzadeh (2012). Moreover, the human capital coefficient is 0.0618 implied that if this coefficient increased by one unit, the economic growth in the studied countries would increase by 0.06 units. In this model, the human capital variable had a positive and statistically significant effect on the relationship between the number of internet users and economic growth. Moreover, the human capital coefficient in both models had a positive and significant effect on economic growth, implying that if the human capital was enhanced by one unit, the economic growth would increase by 0.43. In both models, investment and trade openness had a positive

Table 1: The reliability test

Result	Levin-Lin-Chu test		Variables / Symbols
	Critical value	Test statistics	
At the level, mana	0.0027	-2.277	Human capital
At the level, mana	0.00001	-3.71885	GDP
At the level, mana	0.0013	-3. 01243	Government consumption expenditure
At the level, mana	0.0000	-4.41081	Economic growth
At the level, mana	0.0000	-0.4305	The inflation rate
At the level, mana	0.9977	2.83398	Internet users
	0.0006	0.32455	
At the level, mana	0.097	2. 33786	Investment
At the level, mana	0. 0009	-3. 12383	Mobile subscribers
At the level, mana	0. 0011	-3. 06071	Commercial openness

Table 2: The cointegration test

ADF*	t-tatistic	Prob
	1. 836766	0. 0331
Residual variance		62892.46
HAC*variance		64106.14

\* Augmented Dickey-Fuller

\*\* - Heteroskedasticity- and Autocorrelation-Consistent (HAC)

Table 3: The research findings

Variables	The first model: internet users			The second model: the number of mobile phones subscribers		
	Coefficient	Statistics t	Probability level	Coefficient	Statistics t	Probability level
Growth (-1)	0.264	0.019	0.000	0.36	12.95	0.000
Internet users	0.357	0.094	0.6404	---	---	---
Human Capital	0.0618	0.069	0.5469	-0.115	5.4	0.000
Internet users Human Capital* Number of mobile subscribers	0.044	0.0009	0.7257	---	---	---
Human. Capital * Number of mobile subscribers	---	---	---	3.64e-10	1.57	11.94
Investment	0.004	0.025	0.02995	-3.9e-10	-1.63	0.1049
Trade	0.044	0.149	0.000	0.09	0.015	0.000
GC	-0.08	0.048	0.000	0.075	11.7	0.000
Inflation	0.000	0.023	114.0	-0.15	-3.45	0.0007
Population growth rate	---	---	---	-----	-----	-----
J-statistic	108	---	---	-0.34	-5.2	0.0000
Prob (J-statistic)	0.675	---	---	123.11	---	---
				0.307	---	---

and significant effect on economic growth. However, inflation rate and GC expenditure had a negative and significant impact on economic growth. The interrupted economic growth also had a positive effect on economic growth of the current period. These findings were consistent with the results reported by Afzal *et al.* (2018) and Katircioglu, (2009). In the second model, there was a significant relationship between the number of mobile phones subscribers and economic growth. This was consistent with the results reported by Ficawoyi (2018). Moreover, a significant relationship was found between mobile phones and economic growth in the countries having more efficient human capital for the employed people with academic education. This seemed to be consistent with the results of self-correlation of fixed effects. More importantly, the interaction between mobile phones and human capital had a positive effect on economic growth. This was consistent with the results obtained by Ficawoyi (2018) and Chachar and Hassan (2013).

#### Sargan test

Sargan test is a method to detect the non-correlation of regression model error sentences and instrumental variables in econometric studies. This test was introduced by Sargan (1958). The Sargan test was utilized to confirm the validity of instrumental variables. The J-statistic and its probability level have been presented at the ending part of Table 3. If the probability level of the J-statistic was greater than 5%, the instrumental variables would have the necessary validity. However, the pvalue method was applied to ensure the validity of the instrumental variables. When the test was done, if the p value of the variable was above 5%, the instrumental variable would have the necessary validity. The extracted p value (s) of the studied variables for both models are presented in Table 4. The results of the Sargan test indicated the validity of the instrumental variables.

The result of the above table, considering the amount of statistics and the calculated probability

Table 4: The instrumental variables' p value

Model	P value
The first model	0.5173
The second model	0.6937

levels, does not reject the null hypothesis that the residual component are not correlated with the instrumental variables; Therefore, the results of the estimated coefficients are statistically confirmed. According to the findings of the [Table 4](#), it can be said that the results obtained from model estimation showed the positive and significant effect of internet on economic growth of the studied countries. Therefore, hypothesis is confirmed, which is consistent with the findings of [Ficawoyi \(2018\)](#). This finding indicates that the Internet, in addition to playing a key role in promoting knowledge and awareness of the countries studied, has reduced consumerism in these countries.

## CONCLUSION

Given the growth of the Internet economy in the world today and the competition of less developed countries to gain a significant share of various commercial, industrial and agricultural markets and services and its impact on global economic growth and the role of education on it, the purpose of this study evaluate the impact of human capital on the relationship between technological advances and economic growth in Southwest Asia within 2000 and 2018. To test the hypothesis, the generalized torque method and Ives 10.0 software were used. The results showed that the Internet affects economic growth, this finding indicates that all communication tools without the Internet cannot be effective even with better training Have a significant impact on economic growth. It was also found that the transfer of the trade openness facilitates technology across borders could lead to more efficient economy, allocate resources to produce better goods in production, and increase the revenue. The relationship between the rate of population growth and economic growth was found to be negative since a low population rate could lead to an increased higher per capita income. The "GC" variable, as the government's annual consumption expenditure on goods and services, or a share of GDP, could affect the economic growth. Given the prominent role of

technology indicators in influencing the economic growth of communities, the role of human capital in enhancing the level of technology and, consequently, economic growth could not be ignored. Thus, it seemed necessary to recommend these countries to: 1) improve the economic growth by strengthening education, technology, and productivity human capital; 2) encourage the manufacturers to produce the goods and software related to information and communication technology by providing specific foreign exchange resources, including low-interest and long-term loans, and granting tax exemptions and facilities such as paying a subsidy to attend foreign exhibitions and offering appropriate discounts on transit of the exported goods; 3) help the producers and consumers in providing the required inputs and variety of goods by developing the foreign relations, increasing the import of goods and services, and reducing the tariff and non-tariff barriers to facilitate the development of the technology sector; and 4) take into account the positive and significant effect of human capital on GDP (economic growth), increase investment in this sector, and improve the quality of workforce.

## Research Limitations

In research work, like any other work, there is a possibility of disturbing factors that hinder the normal flow of affairs and affect the research results. It is obvious that the effect of these factors in some cases reduces the results of research and in some cases causes them to be more intense. The main limitations of the present study that could possibly affect the generalizability of the research results are:

- Given that the present study was conducted in some countries of Southwest Asia, so the results cannot be generalized to other developed countries;
- The existence of some conditions such as unexpected events and political conditions that affect companies (in the micro state) and the country (in the macro state), have not been considered in the present study. Therefore, caution should be exercised in generalizing the research results.



### AUTHOR CONTRIBUTIONS

M. Poorahsham, performed the literature review, questionnaire design and analyzed and interpreted the data, prepared the manuscript text, and manuscript edition.

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### CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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### ABBREVIATIONS

**ARDL** Autoregressive Distributed Lag

**ADF** Augmented Dickey-Fuller  
**GC** Government consumption  
**GDP** Gross Domestic Product GDP  
**GMM** Generalized Method of Moments  
**ICT** Information and Communications Technology  
**OPEC** Organization of the Petroleum Exporting Countries  
**WDI** World Development Indicators  
**2SLS** the Two-Stage Least Squares method

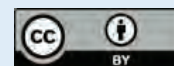
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ORIGINAL RESEARCH PAPER

Evaluation of the impact of strategic human resource management subsystems on improving innovation capability

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ABSTRACT

**BACKGROUND AND OBJECTIVES:** Today, creative and innovative manpower is one of the most important assets and capital of organizations. Although strategic human resource management can be effective in enhancing employee innovation capability, not many research examined the impact of this type of management subsystems on innovation. Therefore, the purpose of current study is to evaluate the impact of strategic HRM subsystems on improving innovation capability in Municipality of Tehran.

**METHODS:** The present study is mixed in terms of applied-developmental purpose and among the researches. In the qualitative stage of the research, the theme analysis method was used and the purposeful participants were selected and interviewed, which included 13 university professors and 19 managers of Municipality of Tehran. Based on the results of the qualitative stage, the strategies of 7 strategic HRM subsystems were identified and a research model was designed. In a quantitative step, in order to validate the model, the structural equation modeling method and smart PLS software were used. For this purpose, while conducting the validity and reliability of the researcher-made questionnaire, 169 managers and experts in Municipality of Tehran who were randomly selected were interviewed.

**FINDINGS:** According to the study, the relationship between strategic HRM subsystems and innovation capability is positive and significant. Also, the results showed that the coefficient of determination for the strategic HRM variable is 0.611, which means that 61.1% of the changes in the innovation capability variable can be predicted with strategic HRM strategies and its subsystems. Moreover, among human resource subsystems, "talent management system and succession management" and "service compensation and reward system" have the greatest impact on innovation capability.

**CONCLUSION:** The results showed that strategic HRM subsystems are effective on innovation capability in Municipality of Tehran, and the results of this study can be utilized and generalized in municipal organizations and public non-governmental organizations that have an almost similar organizational structure.

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## INTRODUCTION

In today's organizations, innovation and creativity are essential in a changing environment, despite increasing competition (Chow, 2017). One of the key factors in creating the ability to innovate to support the performance of the organization is to support the quality of human resources, which should be the first priority (Rajiani et al., 2016). When companies develop new products and improve management processes, they need the motivation and ability of human capital to generate creative ideas, develop innovative approaches, and apply new opportunities (Scarbrough, 2003). The problem that both academics and practitioners face is that innovation management poses a multifaceted problem for organizations that requires strategies, including human resource strategies that affect the set of related factors and influence them. Link together (Sparrow, 2016). Nowadays, the value of strategic Human Resource Management (HRM) is increasingly recognized by management researchers and professionals, and from the perspective of experts, selection, training, rewards and performance and other issues related to employees play an important role in the performance of an organization (Ahmad, 2010). The problem faced by both academics and practitioners is that innovation management poses a multifaceted problem for organizations whose solution requires the adoption of strategies such as human resource strategies that affect the set of relevant factors and influence them. Connect (Sparrow, 2016). Today, the value of strategic HRM is increasingly recognized by management researchers and professionals, and from the perspective of experts, selection, training, rewards and performance and other issues related to employees play an important role in the performance of an organization (Ahmad, 2010). Strategic HRM research focuses on the contribution that human resource actions can make to organizational performance and competitive advantage (Collins and Clark, 2003). In other words, strategic HRM consisting of selection, recruitment, training, performance appraisal, reward, recognition, etc. can help to create a system that is committed to better products, services and experience and in turn facilitates innovation (Singh, 2018). Strategic HRM practices play a central role in creating an environment that nurtures human capital for creative behaviors at work and strengthens skills in solving creative problems (Marchington,

2015). According to Chen and Huang (2009), strategic human resource actions can strongly influence the company's innovation performance, they typically face relatively higher levels of uncertainty, risk, and instability in the innovation process. For instance, the use of an innovation-based recruitment and selection process often plays a key role in ensuring that talented groups of innovation-based individuals are selected to ensure organizational competitiveness (Farouk et al., 2016). Or a reward system can promote innovation in an organization and also, intangible and tangible motivations can be used to encourage employees to create and share innovative ideas (Tsai, 2017; Zopiatis and Theocharos, 2018). Today, various units are in charge of managing public affairs and providing needs and providing services to members of the community. Non-governmental public organizations are among the newest institutions and establishments that have been created as a new phenomenon in public administration and show the highest level of decentralization in public administration and have emerged with the aim of providing some special public services and independence that have freedom of action. Article 5 of the General Accounting Law of the country, approved on 3.26.1987, states in the definition of these institutions: "According to this law, non-governmental public institutions and organizations are specific organizational units that are formed or are formed with the permission of the law, in order to perform duties and services that have a public aspect" Pursuant to the note of an accounting law, the list of non-governmental public institutions and establishment was approved by the parliament on 10.7.1994, according to which 10 organizations and their affiliated institutions, including municipalities, were recognized as non-governmental public institutions (Iran General Accounting Law of the country, 1987). The Municipality is a public non-governmental organization that was established on June 3, 1907 under the name of "Baladieh" and is in charge of the urban management of Tehran, the capital of Iran. The management of this organization is the responsibility of the mayor of Tehran. Municipality of Tehran, based on the latest organizational reforms approved in the first half of 2021 with 8 deputies, 22 districts, 33 general administrations, 22 organizations and 24 subsidiaries, which are intentionally responsible for missions such as: rail and bus transportation, city maintenance and environment,

fire, physical protection, finance, urban planning, human resources, urban and cultural infrastructure and urban development. Although measures have been taken in the Municipality of Tehran to promote staff creativity and innovation, but so far, the capacity of strategic HRM and its subsystems has not been used to promote innovative activities and so far, no research has been performed on the relationship between strategic HRM subsystems and innovation capability, and what strategies can be used in human resource subsystems to enhance innovation capability. So there are questions in this regard: What are the strategies of strategic HRM subsystems to promote innovation capability? What is the impact of strategic HRM subsystems on promoting innovation capability and which of the strategic HRM subsystems has the greatest impact on promoting innovation capability? The main purpose of this study is to assess the impact of strategic HRM subsystems on improving innovation capability in the Municipality of Tehran in order to fill the existing research gap and create scientific and practical results.

#### *Theoretical Foundations*

Innovation is the combination of new and old ideas with knowledge in a way that leads to the creation of products and services, techniques and methods, organizational forms and markets (Tidd and Bessant, 2020). Innovation includes not only product innovation, but also other forms such as process innovation, business model innovation, organizational structure, branding, marketing, management systems, experience, and customer service (Neely and Hii, 2012). The Oslo Manual, developed by the Organization for Economic Co-operation and Development (OCED), describes some aspects that can be used to measure innovation performance in the form of innovation output (e.g., number of new products produced, quality enhancement), as well as improving existing systems in the company) and the impact of innovation (such as changes in competition, market development, increased productivity, profits and environmental impacts) (Aryanto *et al.*, 2015). In addition, according to Fontana (2011), five dimensions of innovation performance can be described: (1) internal; (2) technical; (3) business; (4) economic; and (5) social performance. In other words, innovation capability is a process during which capabilities need to be renewed and strengthened, resource allocation

must be changed, the organization should be revised, and strategies are re-evaluated. Achieving innovation capability is not a coincidence, but the organization needs to pursue innovation as part of its strategy (Zawislak *et al.*, 2013). Innovation capacity can be considered as a set of resources, capabilities and dynamic capabilities dedicated to the innovation process (Pierre and Fernandez, 2018). Innovation capacity not only coordinates and develops the enterprise innovation process, it also allows the firm to generate output through the inputs of the innovation process (Boley *et al.*, 2014). On the other hand, HRM as policies and actions required for individuals or human resources in management positions such as selection, job design, training, performance appraisal, service compensation, job planning and encouraging employee participation in decision making and evaluation Performance is defined (Nayyab *et al.*, 2011). From Armstrong (2001), point of view, HRM as a strategic approach to company decision-making and planning in relation to employees and strategies, policies and actions related to recruitment, training, development, performance management, service compensation and employee relations are integrated horizontally with each other and vertically with the company's strategy. The field of strategic HRM includes the factors that determine decisions about human resource actions, the composition of human capital resources, the characteristics of the behaviors required by human resources, and the effectiveness of these decisions according to different business strategies or competitive conditions (Buller and McEvoy, 2012). Experts have proposed various functions for strategic HRM (Milligan and Maloney, 1996); functions that included career path work, training, outcome-oriented evaluation, employee safety, service rewards, and career development. Chen and Huang (2009) in a research have identified factors such as training, performance appraisal, service reward and employee participation as components of strategic HRM functions. Dhar (2015) mentioned hiring, participation, training, performance appraisal as the most effective strategic human resource measures, according to which employees develop themselves in an innovative and competitive way. Given the importance of innovation in improving the performance of employees in organizations, in the current study, efforts have been made to investigate the effect of strategic HRM subsystems on innovation



capability in the Municipality of Tehran.

#### Research background

In various studies, the relationship between HRM and its subsystems with organizational innovation has been investigated. Mohammadi and Jahanian (2020) in a study, addressed the issue of improving the service compensation system as a driver of human capital innovation. According to the results, service compensation should be flexible in order to encourage and develop entrepreneurial and creative behaviors. Therefore, in compensating employees, habits, beliefs, skills, human relations, values and justice in payment should be considered and more attention should be paid to non-financial rewards. Asgari *et al.* (2020) concluded that performance appraisal affects the creativity and innovation of knowledge workers. Hajazi *et al.* (2020) in a study examined the role of talent management in the emergence of innovative capabilities in a government organization. The results showed that talent management by considering the modifying variables (individual, environmental, organizational, human, contextual and cultural) is effective in the emergence of innovative capabilities. Findings of Mirza Hakim and Poursaid (2018) showed that there is a direct and significant relationship between talent management and organizational innovation. The best predictor of organizational innovation is talent acquisition. Rajabi *et al.* (2016) in a research showed that human resource development activities affect employee innovation with the mediating role of knowledge management and organizational learning. Findings of Hakami *et al.* (2014) showed that 43% of employee innovation development can be predicted by service compensation strategy indicators. The greatest impact is related to creating opportunities for growth and promotion, and in the next stage, freedom and job opportunities, and attractive and attractive work. Azizi *et al.* (2021), examined innovative HRM strategies during the COVID-19 epidemic. Based on the results, innovative HRM strategies including flexibility, strengthening internal efficiency, talent identification and making innovative changes based on organizational evaluation and job activity needs were identified. The results of Singh (2018) research also showed that strategic HRM affects the performance of innovation, in this regard, the capacity of knowledge management as a

mediating variable. According to research by Sharma and Gursoy (2018), reward systems are a necessary tool to encourage employees to create and share new ideas. Therefore, it can be said that innovation-based rewards require compensation for employee services based on innovative ideas that have been created or shared. Findings of Farouk *et al.* (2016) showed that using an innovation-based recruitment and selection process often plays an important role in ensuring the selection of talented groups and innovators to innovate to ensure organizational competitiveness. Aryanto *et al.* (2015), in a research concluded that strategic HRM practices have a positive relationship with innovation capability, which in turn has a positive effect on innovation performance. Therefore, strategic HRM can be a good predictor of a company's innovation capability. Summary of the review of theoretical foundations and background research shows that many studies have emphasized the importance of HRM in promoting organizational innovation and research has confirmed the relationship between them; however, by examining the results of the research, it was realized that the relationship between strategic HRM subsystems and innovation capability and what strategies can be used in strategic HRM subsystems to promote innovation capability, have not been studied in previous studies. Therefore, the present study seeks to fill the existing research gap and evaluate the impact of strategic HRM subsystems on improving innovation capability in the Municipality of Tehran in a practical and comprehensive format. The current study has been carried out in Tehran in 2021.

#### MATERIALS AND METHODS

The main purpose of this study is to evaluate the impact of strategic HRM subsystems on improving innovation capability in the Municipality of Tehran. This research, in terms of purpose, is a development-applied research that is in the group of the mixed methods. Mixed research is a kind of research that is done using a combination of two sets of quantitative and qualitative methods (Bazargan, 2008). On the other hand, it seeks to develop theories and concepts in the field of strategic HRM and its subsystems to promote innovation, the results of which can be used by the managers in the Municipality of Tehran, to promote creativity and organizational innovation. Of course, the results can be used for public and private

organizations, taking into account their background conditions. Also, since the subject of research is new and innovative and there is limited knowledge and understanding about the impact of strategic HRM subsystems on promoting innovation capability, it is considered as exploratory research. In order to identify the strategies of strategic HRM subsystems and the dimensions of innovation capability, the theme analysis method was used and also, in order to confirm the validity of the designed model, the structural Equation Modeling (SEM) method was used. Theme analysis is a method for determining, analyzing and expressing patterns (themes) within data. This method in itself organizes the data and describes it in detail, but can go beyond this and interpret various aspects of the research topic (Braun and Clark, 2006). The data needed to design and validate the research model were collected using semi-structured interview tools and a questionnaire. After reviewing the theoretical foundations and previous research, the interview questions were designed based on the existing research gap according to the objectives of the research. Participants in the semi-structured interviews were university professors and managers in the Municipality of Tehran. In order to conduct semi-structured interviews and model design, a total of 13 university professors and 19 executive experts who were purposefully selected participated in the survey. Interviews continued until theoretical saturation was reached. The selected academic experts had a doctorate in management or related fields and had conducted many research in the field of HRM. Executive experts, while having at least a master's degree, had at least 3 years of management experience in the Municipality of Tehran. During the interviews, the researchers were very careful and tried not to deviate from the defined structure of the interviews and also, the interviewees answered the questions in a calm and trustworthy atmosphere. After conducting interviews and extracting data, coding steps were performed to finally identify the components of the research model. After designing the research model, its validity was measured based on criteria related to the validity of qualitative research. Several criteria for the internal validity of the results of the qualitative method are presented. In this research, triangular methods and expert review were used. The triangular method uses multiple data sources or multiple methods

to validate emerging data. Also, in the method of Member's Check, respondents are asked to answer the question of the acceptability of the results (Koelsch, 2013). In order to confirm the validity of the results of the theme analysis, 3 university professors and 2 executive experts were consulted about the obtained results and the results were approved by making corrections. Also, the obtained results were adapted to the theoretical foundations and previous researches in order to confirm the appropriate compatibility. In the quantitative stage of the research, to confirm the validity of the model designed in the qualitative stage in the Municipality of Tehran, the SEM method and smart PLS software were used. In order to collect data at this stage, a questionnaire designed by the researcher was used which consisted of 56 questions. The validity of the questionnaire designed by 3 experts in the qualitative stage was confirmed by making corrections. Also, the reliability of the questionnaire was calculated by Cronbach's alpha method as 0.803, which was a suitable value. The statistical sample at this stage was 169 managers and specialists in the field of human resources in the Municipality of Tehran. The sample size at this stage was calculated by Cochran's method and the sampling method was random.

## RESULTS AND DISCUSSION

In the present study, in order to identify the strategies of strategic HRM subsystems and the dimensions and components of innovation capability, the theme analysis method was used. For this purpose, after conducting semi-structured interviews with experts, their content was examined. The steps taken to design the model based on the view of Brown and Clark (2006) using the theme analysis method are as follows:

*Step 1 - Familiarity with the data:* In the first step, the content of the interviews was examined and this was repeated several times to ensure that no point was missed.

*Step 2 - Creating the initial codes:* After reviewing the content of the interviews, for the items stated by the experts, the initial codes were extracted by the researchers. The method was that the researchers extracted a code for the points made by the interviewees that referred to a specific topic.

A sample text of the interviews and the extracted codes are provided in Table 1.

Table 1: Sample text of interviews and extracted codes

Row	Interview text	Strategy
1	Some people who are hired in the municipality enter the system using relationships and not organizational needs, and some of them are not qualified people. However, many elites who can transform the system with their creative knowledge and mind cannot be absorbed by the system.	Elitism
2	The entry of unqualified people into the organization through the relationship not only lowers the overall performance of the system, but also reduces work ethic and motivation among employees, and the become indifferent and discouraged.	Ethical
3	The recruits must be able to meet the future needs of the municipality. Meeting the demands of citizens, which is changing day by day, requires creativity. Even the people the system needs in the future need to be retained in the organization.	Foresight
4	Due to the increase in the level of knowledge and skills of employees, performance metrics should be focused on results instead of behaviors. For instance, the number of innovations in work or the amount of improvement made by employees should be evaluated.	Emphasis on results

Table 2: Strategies of strategic HRM subsystems and dimensions and components of innovation capacity

Variable	Dimension	Component
Strategic Management of Human Resources	RE	Elitism
		Ethical
		Foresight
	EV	Emphasis on results (rather than behaviors)
		Emphasis on continuous performance improvement
		Incorporating innovative benchmarks in performance appraisal
	DE	Enhancing staff knowledge
		Targeted and effective education
		Development of innovative skills
	CO	Axis justice in payment
		Rewards for innovative activities
		Emphasis on employee performance in payment
	AN	Flexibility of the payment system for knowledge employees
		Promoting job enrichment
		Significantly strengthen jobs
TA	Employees' independence and freedom of action	
	Identifying and discovering talents	
	Fostering talents	
Innovation capability	RE	Succession planning for key and specific jobs
		Employees' tacit knowledge management
		Participatory Management
	ID	Employee support
		Strengthen relationships with creative and innovative employees
		Creating a platform for creating ideas
	AB	Idea creation function
		Staff recruitment capacity
		Ability to absorb the environment of the organization
	AP	Absorption capacity of processes and procedures
change management		
Organizational and management system support		
PE	Product. service innovation	
	Process innovation	
		Innovation in work procedures

*Step 3 - Search themes:* In this step, the codes that were related to a specific field were combined by the researchers in the Theme format.

*Step 4 - Review themes:* Once the themes have been identified, the researcher re-examined them to make sure they were correct, and finally, the final theme map was prepared.

*Step 5 - Defining and naming themes:* After finalizing the themes, the researcher chose the appropriate name for each theme.

Finally, the strategies of strategic HRM and innovation capabilities subsystems are shown in Table 2.

Finally, in the research model, 7 strategic HRM subsystems that were approved by the experts were included in the model. These subsystems include staff recruitment, supply and adjustment system, performance management system, human resource development system, service compensation and reward system, job analysis and design system, talent management and succession management system and employee relations management system. Also, the dimensions related to the promotion of innovation capability, which include the ability to create ideas, the capacity to absorb innovation, the capacity to apply innovation and innovative performance, were included in the model. The model of strategic HRM

with the approach of promoting innovation capability in The Municipality of Tehran is shown in Fig. 1.

#### Research model validation

SEM was used to validate the research model. Initially, the adequacy of the research samples was examined. There are several methods for assessing the adequacy of sampling, including the KMO test, the value of which always fluctuates between 0 and 1. On the other hand, Bartlett (t) test was used to ensure the appropriateness of the data that the correlation matrix that is the basis of the analysis in society is not equal to zero. In other words, sampling adequacy can be confirmed by using Bartlett test. The results of the KMO and Bartlett tests are presented in Table 3.

According to Table 3, the size of the sample adequacy index (KMO) is 0.814 and is larger than 0.6, which indicates that the sample size is sufficient. Also, the results of the significance test of the sphericity of Bartlett sample with SPSS software is equal to 0.000 which indicates the adequacy of the samples. After confirming the adequacy of the sample size, reliability and validity were examined. Two criteria (Cronbach's alpha coefficient and composite reliability coefficient) were used to determine the reliability of the questionnaire. Cronbach's alpha

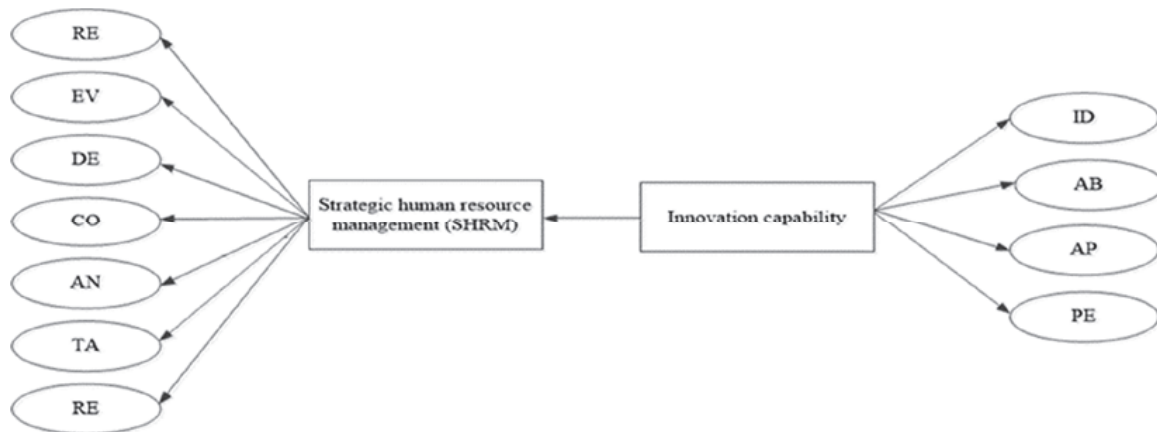


Fig. 1: Research conceptual framework.

Table 3: Results of KMO index and Bartlett test calculation

Index	KMO	Bartlett	Sig	Degrees of freedom	Test result
Value	0.814	32125.87	0.000	5125	Confirmed

Table 4: Calculated Factor Load Values, Cronbach's Alpha, Combined Reliability and Convergent Validity

Demotion	CA*	CR**	AVE
Employee Recruitment, Supply and Adjustment System (RE)	84.0	86.0	72.0
Performance Management System (EV)	80.0	84.0	75.0
Human Resource Development System (DE)	86.0	89.0	73.0
Service Compensation and Reward System (CO)	85.0	89.0	76.0
Job Analysis and Design System (AN)	82.0	83.0	71.0
Talent Management and Succession Management (TA) System	86.0	88.0	81.0
Employee Relationship Management System (RE)	81.0	84.0	68.0
Ability to create ideas (ID)	82.0	83.0	69.0
Innovation Absorption Capacity (AB)	83.0	85.0	73.0
Innovation Application Capacity (AP)	79.0	83.0	72.0
Innovative performance (PE)	80.0	81.0	75.0
<b>Minimum acceptable amount</b>	7.0	7.0	5.0

\* Cronbach's alpha

\*\* Combined reliability

Table 5: Diagnostic validity of the dimensions of the research model

Dimension	RE	EV	DE	CO	AN	TA	RE	ID	AB	AP	PE
RE	0.816										
EV	0.324	0.829									
DE	0.388	0.409	0.791								
CO	0.335	0.387	0.298	0.834							
AN	0.320	0.288	0.405	0.339	0.777						
TA	0.336	0.395	0.425	0.337	0.358	0.868					
RE	0.390	0.312	0.285	0.396	0.433	0.319	0.758				
ID	0.326	0.284	0.312	0.271	0.366	0.294	0.377	0.810			
AB	0.346	0.28	0.355	0.377	0.368	0.27-	0.341	0.415	0.792		
AP	0.337	0.379	0.352	0.291	0.389	0.316	0.348	0.431	0.447	0.743	
PE	0.269	0.342	0.374	0.317	0.287	0.396	0.387	0.402	0.416	0.437	0.796

coefficients of all variables in this study are more than the minimum value of 0.7, therefore, reliability is confirmed. Also, the validity was calculated in two parts of divergent and convergent validity. The AVE criterion is the convergent validity calculation index and represents the average variance shared between each structure with its own indicators. The Average Variance Extracted (AVE) criterion is the convergent validity calculation index and represents the average variance shared between each structure with its own indicators. Simply put, AVE indicates the degree of correlation of a structure with its characteristics that the higher the correlation, the greater the fit. [Fornell and Larcker \(1981\)](#) introduced the AVE criterion for measuring convergent validity and stated that a value of AVE above 0.5 indicates acceptable convergent validity for measurement models.

Also, the criterion used to calculate the divergent validity is the degree to which the structure is related to its indicators compared to that structure with other structures. Acceptable divergent validity

of a model indicates that a structure in the model has more interaction with its indicators than other structures ([Davari and Rezazadeh, 2014](#)). The results of the divergent validity test are presented in [Table 5](#).

After confirming the adequacy of the sample size and the validity and reliability, the structural model of the research was tested. The output of PLS software indicates the appropriateness of a fitted structural model. The tested conceptual model is presented in [Figs. 3 and 4](#). The numbers written on the lines are actually beta coefficients from the regression equation between the variables, which is the same as the path coefficient, and the numbers inside each circle represent the value of  $R^2$  for the hidden endogenous variables of the model. As can be seen in [Fig. 2](#), the effect intensity between human resource subsystems and the innovation competition is 0.611, which is significant with respect to t values.

It should be noted that the most basic criterion for measuring the relationship between structures in structural equation models is the significant numbers



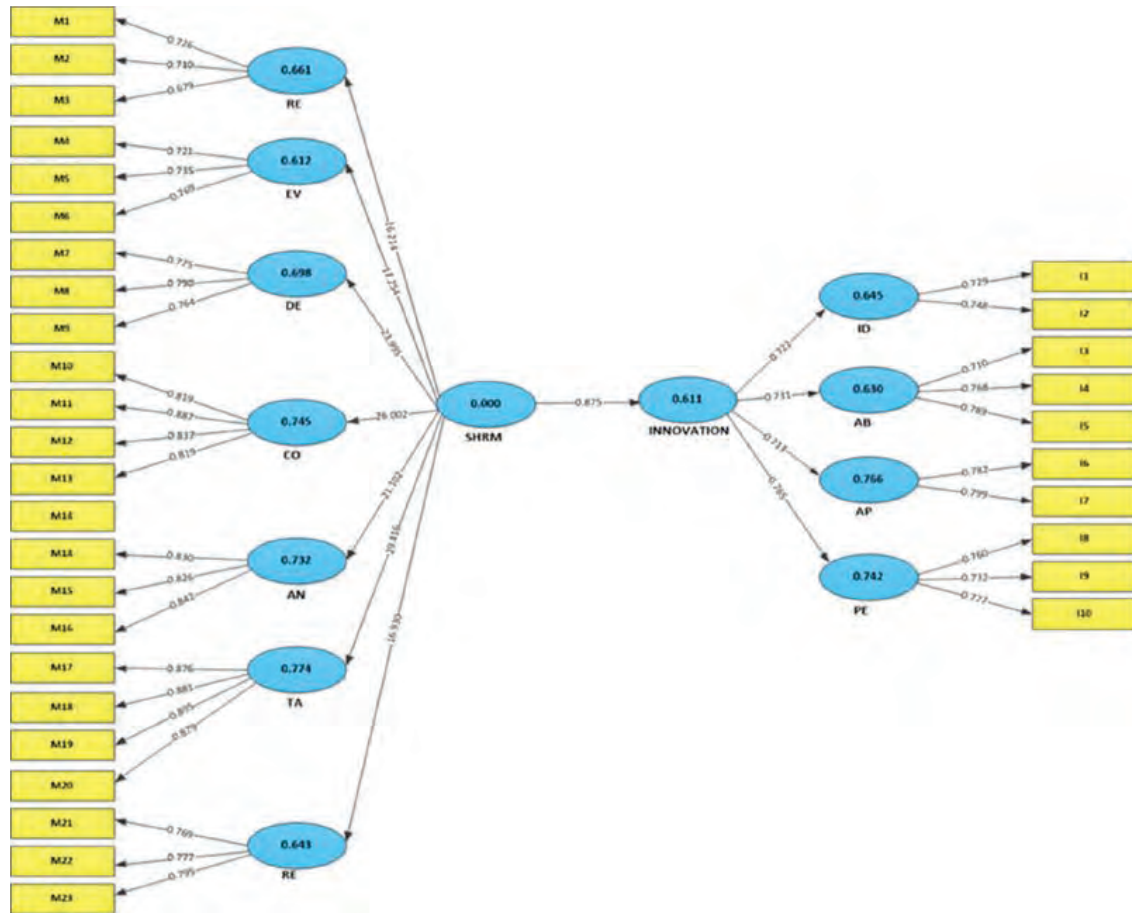


Fig. 2: Structural model of research in standard mode

t. If the value of t-statistic is outside the range (-1.96 to +1.96), it is significant at the 95% confidence level, and if the value of statistic is placed within this range, then the estimated path coefficient is not significant and the corresponding hypothesis is rejected. Fig. 3 shows the conceptual model of the research in the significant state of coefficients. As can be seen, all coefficients are out of range and therefore, all of them are significant.

To evaluate the fit of the structural model, the coefficient of determination of the endogenous latent variables of the model was calculated. Chen and Huang (2009) defined the three values of 0.19, 0.33 and 0.67 as the criterion values for the weak, medium and strength values of the structural part of the model by the coefficient of determination. According to the results of calculations, the value of the coefficient of determination of the innovation capability variable is

0.611, which is a suitable value. The structural model quality test (Q2) was proposed by Stone (1974) for the predictive power of the model. They believe that models that have an acceptable structural fit should be able to predict the characteristics of the model's endogenous structures. If the value of Q2 in the case of an endogenous structure is zero or less than zero, it indicates that the relationship between the other structures of the model and that endogenous structure is not well explained and therefore the model needs to be modified. Hensler et al. (2009) set three values of 0.02, 0.15 and 0.35 regarding the intensity of forecasting power for endogenous structures. The value of Q2 for the innovation capability variable is 0.31, which is the optimal value. Finally, the GOF criterion is related to the overall fit of the structural equation models, which means that the researcher can test the correctness and overall fit

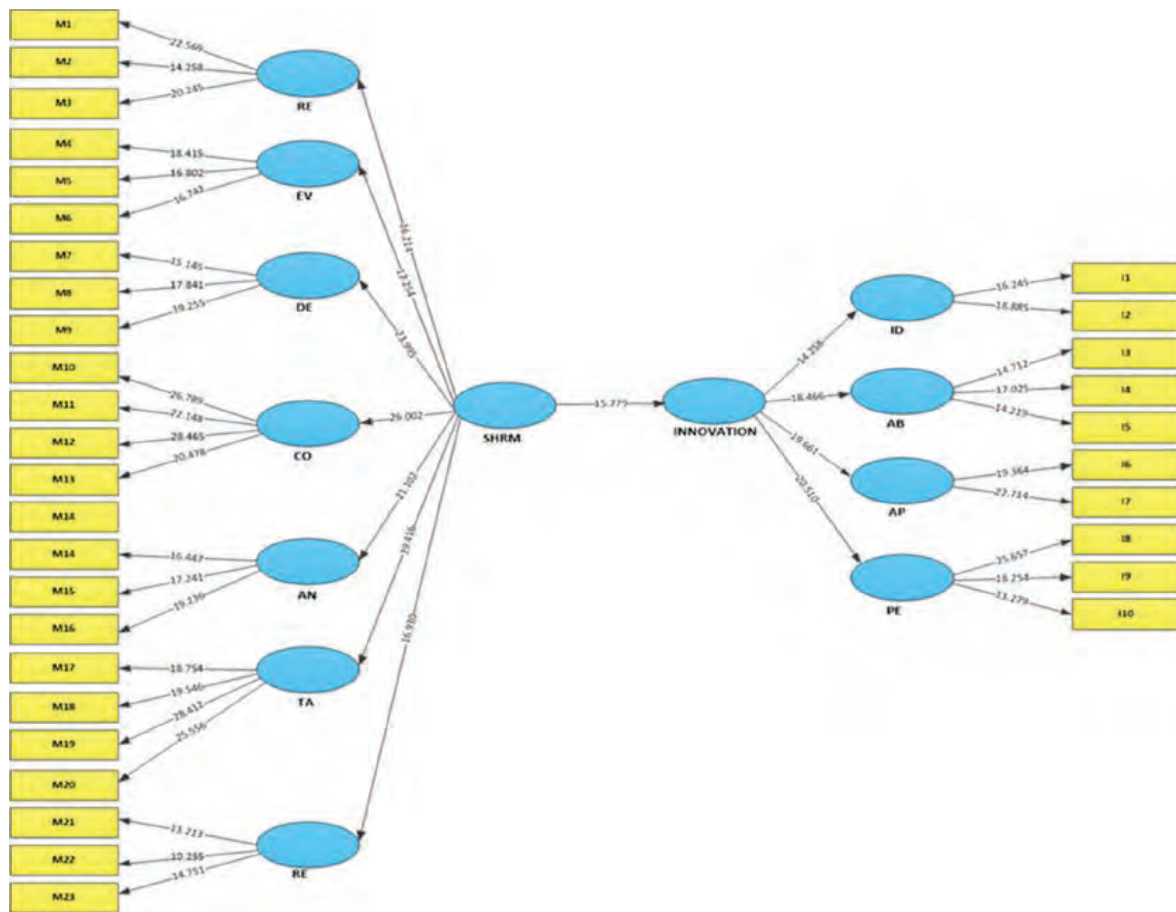


Fig. 3: Structural model of research in the significant coefficients mode

of the proposed conceptual model with this criterion. In GOF criterion, three values of 0.01, 0.25 and 0.36 have been introduced as weak, medium and strong values for this criterion (Davari and Rezazadeh, 2014). The calculated GOF value for the research model is 0.34, which is an acceptable and strong value. Based on the results of the research, 23 strategies were identified for strategic HRM subsystems that can provide the basis for promoting innovation capability. Also, based on the findings of the model validation, the impact of 7 subsystems of employee recruitment, supply and adjustment system, performance management system, human resource development system, service compensation and reward system, job analysis and design system, talent management and succession management system and management system relationships with employees on promoting innovation in the Municipality of Tehran were

confirmed. In addition, among the strategic HRM subsystems, "talent management and succession management system", "service compensation and reward system" and "job analysis and design system", with a coefficient of determination of 0.774, 0.745 and 0.732 were identified as the most effective subsystems in promoting innovation capability. Considering the identification of the strategies of each subsystem and the approval of all of them, a systematic model can be used to promote the innovation capability in the Municipality of Tehran. The results of the research are consistent with the results of other researches. In the research of Mohammadi and Jahanian (2020), Tsai (2017) and Zopiatis and Theocharous (2018) and Sharma and Gursoy (2018), the system of service compensation and reward has been proposed as a stimulus for human capital innovation. In the present study, the effect of the compensation system Services

and strategic rewards on innovation capability were confirmed. Also, in the study of [Asgari et al. \(2016\)](#), the effect of employee performance appraisal on innovation was emphasized, which was also confirmed in this study. [Farouk et al. \(2016\)](#) also confirmed the relationship between recruitment and employment system with innovation, which is consistent with the results of the present study. [Hajazi et al. \(2019\)](#) and [Mirza Hakim and Poursaid \(2018\)](#) and [Azizi et al. \(2021\)](#), in their research, confirmed the impact of talent management system on innovation, which in this study, strategic talent management system, as the most important strategic management subsystem of human resources management were identified in promoting innovation capability.

## CONCLUSION

Today, human resources play a key role in the success of organizations and leading organizations have creative, motivated and capable employees. Certainly, in addition to the characteristics of employees, the actions related to strategic HRM that are planned and implemented by organizations are effective in believing in capabilities and creating energy and motivation in the Municipality of Tehran, like any other organization, is no exception to this rule and needs to use the capacity of strategic HRM and its subsystems to strengthen the ability to innovate in order to properly respond to the demands of citizens and other stakeholders and adapt to changing environmental conditions which the current study addressed this important issue. In this study, first, the strategies of 7 strategic HRM subsystems were identified with the approach of promoting innovation capability by consulting with the experts, and then the relationship between human resource subsystems and innovation capability was examined through consulting managers and human resource professionals. As the results showed, strategic HRM subsystems are effective on innovation capability in the Municipality of Tehran. In addition, among the strategic HRM subsystems, "talent and succession management system", "service compensation and reward system" and "job analysis and design system" were identified as the most effective subsystems in promoting innovation capability. Considering the strategies of each subsystem and identifying all of them, a systematic model can be used to promote

innovation in the Municipality of Tehran. The results of the current study can be applied and generalized in terms of application in municipal organizations as well as non-governmental public institutions that have an almost similar organizational structure.

## Suggestions

Based on the research results, the following practical suggestions are presented:

- It is suggested that the management of the Municipality of Tehran to examine the gap between the current situation and the desired condition in each of the strategic HRM subsystems based on the identified strategies, and formulate strategies and policies needed to move towards the desired conditions;
- It is recommended that the management of the Municipality of Tehran to use the experiences of successful national and international organizations in the field of implementing the identified strategies in each of the strategic HRM subsystems;
- In order to implement the identified strategies as effectively as possible, it is suggested that the management of the Municipality of Tehran to use the opinions of operational and middle managers and form committees with their membership to implement each of the strategies;
- It is suggested that in order to prevent the ineffectiveness of each of the strategies identified in the subsystems, a strategic council should be formed in order to continuously monitor and review environmental and internal factors and adapt programs and executive measures.

## AUTHOR CONTRIBUTIONS

S. Amani performed the literature review, experimental design, analyzed and interpreted the data, prepared the manuscript text, and manuscript edition. M. Mousakhani helped in the design of experimental and manuscript edition. K. Daneshfard helped in the manuscript preparation and final edition.

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### CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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### ABBREVIATION

CA	Cronbach's alpha
CR	Combined reliability
HRM	Human resource management
GOF	Goodness Of Fit
KMO	Kaiser-Meyer-Olkin Measure of Sampling Adequacy
OCED	Organization for Economic Co-operation and Development
PLS	Partial Least Squares
SEM	Structural Equation Modeling

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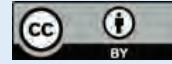
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