

Intensity and Diversity of Use as a Tool to Measure the Quality of Public Spaces

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Abstract

The intensity and diversity of human activities in public open spaces are indicators of their success and high quality. Although some studies addressed the relationship between the quality of open spaces and their use, none has comprehensively addressed the intensity and diversity of use and users. This study attempts to develop the Mehta method 2007 "GPSI" for measuring the quality of public open spaces, by adding the spatial dimension and using the time dimension more widely. Procedures for developing a tool for measuring the intensity and diversity of use (IDU) were applied to four selected public open spaces in Sana'a city in Yemen by the survey studies. The tool of (IDU) includes the intensity of temporal use, the intensity of spatial use, the intensity of social use, diversity of age and gender, the intensity of stay, and the intensity of activities. This study used the perception of architects and urban designers to determine the quality of public space (QPS). It then examined the correlation between IDU and QPS using *Pearson's Correlation Coefficients*. The results show significant correlations between indexes of IDU and QPS.

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1. Introduction and Literature Review

A public open space is an essential key to the local political and social life. Streets, squares, and parks are spaces where various people will demonstrate, socialize, and experience disparity. They contribute to the reputation of cities for vibrancy and livability and local citizens' well-being [1]. Also, public spaces are used as the basic denominator for a decent social life [2]. Public space is a common space for everyday life such as going to work or learning, meeting and making friends, walking and strolling, hanging out and relaxing, and the rest of everyday life [3]. It includes everywhere that people can access freely in their built and natural environment [4], and they have the right to participate in the events [5]. One of the significant roles of public open spaces is fostering personal and cultural diversity, which reflects equality in public open spaces [6]. Interaction between diverse populations in outdoor areas helps to promote respect and tolerance, rather than segregation in mono-culture environments. Public open spaces can also provide medical benefits, boost fitness and health when used in physical exercise, or when people only go out to give a sense of well-being that is very significant with the increasing age-related diseases such as heart disease and diabetes arising from modern lifestyles [7]. Public open areas are also places to learn unofficially by meeting people with various cultures and traditions [8]. Many studies have pointed out that the usability of open spaces is related to their characteristics and quality. They dealt with the relationship between the space quality or the characteristics of space and people's behavior and perception using several terms such as the use of pattern or usability [9-22], vitality [23], social interaction or social sustainability [24-26], and walkability [27-30]. On the other hand, Gehl (1987, 2011) determines the quality of public open space by the kind of activities that occurs in it [31], [32]. When spaces are of low quality, only necessary activities take place. Nonetheless, optional social activities of higher quality spaces might occur, increasing social activities. Gehl has also categorized the activities that occur in public open spaces into three types: necessary, optional, and social activities [31], [32]. Necessary activities are all the practices most people have to do, such as waiting for a bus, going to study, walking to work, shopping, etc. This class primarily belongs to daily activities. Because this category of tasks is necessary, the physical environment affects it very little. These events often happen every day of the year, regardless of the weather, as there is no alternative. Optional activities are those practices that occur as a response to peoples' desires even if the place conditions and weather encourage that. These events

include: taking a walk, relaxing, lying in the sun, etc. This class of activities depends entirely on the characteristics of the outdoor environment and particularly good external conditions. The most significant factor can be the weather. Most of all outdoor recreational activities are included in this category. Social activities are probably a result of accidentally occurring events when people are out and doing some of the other two kinds of activities. Social activities can include kids playing with each other, handshakes and greetings, conversations, group activities, shared social activity—meeting, and seeing and hearing other people. Social activities might have different features depending on the situation where they exist.

Shehayeb, (2008) has pointed out that public spaces cannot be designed for a specific activity or single type of user. Public spaces should accommodate many diverse activities and multiple groups of users. The high level of the multiplicity and diversity of activities and users can indicate the quality of public space [33]. While Mehta, (2007) has released a tool to measure the quality of public spaces that adopts the degree of diversity of use and users and duration of stay in space as indicators to measure the effectiveness of public space, which is based on the intensity of use, the intensity of temporal use, the intensity of social use, length of stay, diversity of users in terms of gender and age, and variety of activities [34]. Although Mehta's tool measures social use diversity, it does not measure the intensity of social use diversity and the persistence of diversity during the periods of the day. Likewise, the tool measures the diversity of usage and users, but it does not measure the intensity of this diversity during periods of the day. The tool also measures the duration of stay in space but does not determine whether the duration equal during periods of the day. Furthermore, it did not address whether the different areas and zones of space are used with the same density and during periods of the day. Determining these indicators in one period of the day may affect the accuracy and objectivity of the results. Also, examining the entire space at one time may lead to inaccurate results on the quality of space, for example, as the diversity of use may occur in certain parts of space without others. The current study deals with these issues by adding the spatial dimension and using the time dimension more widely. It proposes a tool for determining the intensity and diversity of use (IDU) that can be an indicator to measure the quality of public space. The density of use must be homogeneous in all parts of space and all periods of the day. Therefore, the indicators and trends of the proposed tool for determining the intensity and diversity of use (IDU) can be as follows:

- **The intensity of temporal use:** *Are the spaces used with the same intensity throughout the day? Is the number of people inside the spaces equal throughout the day?*
- **The intensity of spatial use:** *Do spaces' users exist in different zones equally?*
- **The intensity of social use:** *Is space social? Does the intensity of social use continue throughout the day?*
- **The intensity of age diversity:** *Is there a diversity in the ages of users? Does this diversity continue throughout the day?*
- **The intensity of gender diversity:** *Is there a diversity in the gender of users? Does this diversity continue throughout the day?*
- **The intensity of stay:** *How long do people spend in space? Are people staying in space with the same intensity?*
- **The intensity of activities:** *Is there a variety of activities? Does the diversity of activities continue throughout the day?*

On the other hand, to ensure that the tool developed in this study measures the quality of public spaces, the study verifies the quality of specific public spaces. Several studies have discussed the relationship between the use and quality of open space in several aspects. This study deals with the quality of public open spaces from four aspects, which are the quality of the physical settings to facilitate the activities, the quality of the atmosphere, the visual quality, and the meanings and the cultural values. The use of the public space is related to the physical settings and the facilities that support and stimulate various activities in the space [35-38] such as: sitting [25], [26], [39], walking [40-42], children and teenage play [43] [44], and sports and physical activities [45-50], and the supporting facilities stimulate the use of public spaces including benches [51], dining tables, drinking fountains[52] , [53], and toilets [54]. Furthermore, the use of public space may be linked to some other related settings and features of public spaces, such as the size of the space [55], the integration and overlap of facilities and activities [19], the separation of pedestrian traffic from the movement of vehicles [53], [56], the provision of surveillance cameras and emergency stations, [48], [50], [57], and the use of information technology for entertainment purposes. The atmosphere quality of public space may also be considered an essential factor in stimulating the intensive use of public spaces. Studies indicate the correlation of a range of spatial settings with the use of public space, such as the diversity of green and natural elements and areas [35], [56], [58], the variety of water features[59], [60], protection of activity areas from natural conditions[61], cleanliness and maintenance of equipment and surfaces[62-65], good lighting [30],

calmness [26], [66], and the space being free from intruders and disturbing behaviors [53], [67]. Several studies indicate that the use of public space may be related to visual properties [26], [68]. This study investigates the visual quality through the diversity of the landscape elements, the unity of shape, size, and colors of the elements, the transparency and visibility in the parts of space, the human scale for the dimensions of the elements and spaces, the space is free from visual distortions, and the harmony of the visual scene image with the surrounding environment. A set of spatial features that enhance meanings and cultural and social values in public space may also have an impact on the use of the space [47], [69-72], such as the distinction and uniqueness of space design, the presence of cultural and historical elements, availability of distinctive and unique elements and landmarks, complexity of space design that creates curiosity. The study assumes that the intensity and diversity of use are positively related to the quality of public spaces. The study uses Pearson's Correlation Coefficients to measure the relationship between IDU and QPS. This tool is applied in four public open spaces in Sana'a city in Yemen, namely Al-Tahrir Square, Al-Saleh Mosque Square, Al-Sabean Park, and Al-Thawra Park. The study develops a quantitative tool that measures the intensity and diversity of use in public spaces that can indicate the quality of these spaces. The tool can be developed, generalized, and used in similar areas.

2. Materials and Methods

2.1. Study Area

Sana'a city is the political and administrative capital and the Yemen's main cultural center [73]. It contains the old city of Sana'a, which has been included in the World Heritage List in 1993. It has been inhabited for more than 2,500 years. In the 7th and 8th centuries, the city became an important Islamic center. This religious and political heritage can be seen by the 103 mosques, 14 hammams and over 6,000 houses. They were built before the 11th century [74]. The old city also has a unique urban and architectural patrimony [75], which can be considered as a record expressing the real story of the human civilization and development in Yemen [76]. Sana'a's urban infrastructure consists of several different types of open areas, such as highways and roads, greenery and public areas, squares of the city, stadiums, open spaces, and open green fields [77]. However, many issues face public open spaces in Sana'a, with the scarcity of studies dealing with open spaces in the city [78]. We, therefore, took the opportunity to apply and test our suggested approach to four chosen

areas in the city. First, we conducted a preliminary survey of Sana'a city's most important public spaces. This survey includes the physical characteristics, accessibility, type of people in the spaces, and activities of the five public open spaces in Sana'a city: **Al-Tahrir Square**, **Al-Thawra Park**, **Al-Sabeen Park**, **Al-Saleh Mosque Square**, and **Bab Al-Yemen**. Four of them have been selected as a case study. Bab Al-Yemen has been excluded because it does not serve the research objectives; it is no longer used as a space to embrace human activities, see Table 1.

Table 1. survey of the most important public open spaces in Sana'a- capital of Yemen

| Features | Public Open Spaces Elements | Al-Tahrir Square | Al-Sabeen Park | Al_Thawra Park | Al-Saleh Mosque Square | Bab Al-Yemen |
|-------------------------------|---------------------------------|----------------------------|-------------------|--------------------------|------------------------|---------------|
| Physical characteristics | Traditional architecture | 3 | 1 | 1 | 1 | 5 |
| | Modern architecture | 3 | 3 | 3 | 5 | 2 |
| | Pedestrian walkways | 3 | 5 | 4 | 3 | 3 |
| | Landscape elements | 4 | 5 | 4 | 2 | 1 |
| | Green spaces | 3 | 5 | 4 | 4 | 1 |
| | Seating areas | 3 | 5 | 5 | 2 | 1 |
| | Play areas | 2 | 5 | 4 | 3 | 1 |
| | Landmarks | 3 | 3 | 2 | 2 | 3 |
| | Good maintenance | 2 | 2 | 2 | 2 | 4 |
| General quality of facilities | 2 | 2 | 1 | 2 | 1 | |
| Accessibility | Convenient location | 3 | 5 | 4 | 3 | 2 |
| | Parking is adequate | 5 | 5 | 5 | 5 | 3 |
| | Easy access | 4 | 5 | 5 | 5 | 4 |
| | Public transportation available | 5 | 4 | 4 | 4 | 5 |
| People | Families | 3 | 5 | 5 | 2 | 3 |
| | Children | 4 | 5 | 5 | 4 | 2 |
| | Singles / adults | 5 | | | 5 | 5 |
| | Middle Age / Youth | 5 | 5 | 5 | 5 | 5 |
| | elderly | 3 | 3 | 3 | 2 | 4 |
| Activities | residential | 2 | 1 | 1 | 4 | 2 |
| | Commercial (Shops + Kiosks) | 3 | 3 | 2 | 2 | 5 |
| | Leisure and entertainment | 3 | 5 | 5 | 2 | 2 |
| | Walking and relaxing | 4 | 5 | 5 | 3 | 2 |
| | Pedestrian traffic | 5 | 2 | 2 | 3 | 4 |
| | Automobile traffic | 1 | 2 | 2 | 2 | 2 |
| | Family activities | 3 | 5 | 5 | 2 | 2 |
| | Children play | 3 | 5 | 5 | 2 | 1 |
| | Sport activities | 2 | 3 | 3 | 2 | 1 |
| street hawkers | 2 | 3 | 3 | 1 | 4 | |
| | | 5 Strongly verified | 4 Verified | 3 Medium verified | 2 Poor | 1 None |

The most important public open spaces in Sana'a, which have been selected as case studies are described below (see Figure 1). **Al-Tahrir Square:** Placed between the two major urban districts. It is the main square of Sana'a and is known as the central plaza. It has a range of popular restaurants, hotels, stores, travel agencies, and the main post office in the city. A beautiful fountain surrounded by the most prominent museum in Yemen is situated at the center of the square. The square is also a famous meeting place for residents. **Al-Saleh Mosque Square:** Al-Saleh Mosque

is the largest mosque ever constructed in Yemen. The mosque was named after President Ali Abdullah Saleh because it was built during his presidency. The square contains green spaces, parking lots, and seating areas. **Al-Sabeen Park:** The Park is best described by its magnificent landscape as well as numerous local events. It is the largest park in Sana'a city and is rich in colourful flowering. **Al-Thawra Park:** It is filled with electric games and green spaces and is one of the most important places for locals, visitors, and tourists.



Figure 1. selected public open spaces in Sana'a city

2.2. Methodology

2.2.1 Determine the intensity and diversity of use

Activities survey is one of the most critical research methods to understand and realize what is happening in space. Surveying different activities helps to understand what is happening in space, how people behave in space, and where and how they conduct their individual and group activities. Demographic data collection also helps to understand the diversity of users. It is hard to comprehend and understand space without spending too much time in space. Activities in space will vary by the day, so the survey should include all days of the week, or at least two working

days, the last working day, and a weekend day. The time within the day plays an essential role in what is happening in space, so it should include all-day periods (morning, noon, afternoon, and evening). Therefore, we have verified all the variables of the proposed tool to measure the intensity and diversity of use for a week in each selected space separately. The surveys included working days and weekends. Four periods each day (morning (07:00 a.m. to 10:30 a.m.), noon (11:00 a.m. to 01:00 p.m.), afternoon (02:00 p.m. to 05:00 p.m.), and evening (06:00 p.m. to 09:00 p.m.)), for a quarter of an hour per period. The quarter of an hour varies daily; for example, if we calculate on Saturday from 09:00 to 09:15, we will calculate from 09:15 to 09:30 on Sunday. This investigation was conducted in June and July 2019 in the selected areas. The working conditions are similar in the summer of Sana'a, which has moderate temperatures. When it was raining, authors would cancel the survey results and repeat the count another day. In each space, authors have counted and calculated the instrument variables as follows:

2.2.1.1 The intensity of temporal use (ITU)

ITU is calculated by dividing the average of all arithmetic means of usage throughout the day by the maximum average. Authors have collected the number of people doing different activities in space in all periods of the day, for a quarter of an hour for each period. We then calculated the average number of people in each period of the day, see Table 4.

$$\text{Average of each period of day} = \sum_{i=1}^m \text{people in the period} / m \quad (1)$$

Where m is the number of dyes.

We then calculated the ITU by dividing the average of all periods by the maximum average.

$$ITU = \frac{(\sum_{i=1}^n \text{average of each period} / n)}{\text{maximum average}} \quad (2)$$

Where n is the number of periods and $0 < ITU \leq 1$. If $ITU = 1$, that means the certain space is occupied at the same degree of density through all periods of the day.

2.2.1.2 The intensity of spatial use (ISU)

ISU is calculated by dividing the average number of people into all zones by the highest value. We have collected the number of people who are doing activities in the different zones of space in all periods of the day, for a quarter of an hour for each period. We calculated the average number of people in each zone for a week, see Table 5.

$$\text{Average of each zone} = \sum_{i=1}^m \text{people in the zone} / m \quad (3)$$

Where m is the number of dyes.

We then calculated the ISU by dividing the average number of people into all zones by the maximum average.

$$ISU = \frac{(\sum_{i=1}^n \text{average of each zone} / n)}{\text{maximum average}} \quad (4)$$

Where n is the zones' number and $0 < ISU \leq 1$. If $ISU = 1$, that means that all zones of the space are occupied at the same degree of density.

2.2.1.3 The intensity of social use (ISCU)

ISCU is calculated by dividing the total number of people within groups by the total number. We have collected the number of people who are being together as groups and the total number of people in the space in all periods of the day, for a quarter of an hour for each period. We then divided the total number of people in groups by the total number of people in space, and we calculated the average as (ISCU). See Table 6.

$$ISCU = \sum_{i=1}^n \left(\frac{\sum_{j=1}^m (\text{people in group})}{\text{Total of people}} \right) / n \quad (5)$$

Where n is the number of days, m is the number of groups, and $0 < ISCU \leq 1$. If $ISCU = 1$, that means the all people in the spaces are being in groups all day.

2.2.1.4 The intensity of age diversity (IAD)

IAD is calculated by dividing the average of all categories by the maximum average. Authors divided the space users into six age groups (0-5, 6-12, 13-18, 19-29, 30-45, and older than 45). Authors counted the number of people in space for each class at all periods of the day, for a quarter of an hour for each period. Then we calculated the rate for each category separately, see Table 7.

$$\text{Average of each age group} = \sum_{i=1}^m \text{people in the group} / m \quad (6)$$

Where m is the number of days.

We then calculated the IAD by dividing the average of each group by the maximum average.

$$IAD = \frac{(\sum_{i=1}^n \text{average of each age group} / n)}{\text{maximum average}} \quad (7)$$

Where n is the number of category groups, and $0 < IAD \leq 1$. If $IAD = 1$, that means that the number of people in space for all groups at all times of the day is equal.

2.2.1.5 The intensity of gender diversity (IGD)

IGD is calculated by dividing each type's average number of individuals by the highest mean. We counted the number of people in space for both sexes at all periods of the day, for a quarter of an hour in each period. Then we calculated the average for each sex during the week (see Table 7).

$$\text{Average of each gender group} = \sum_{i=1}^m \text{people in the group} / m \quad (8)$$

Where m is the number of days.

We then calculated the IGD by dividing the average of each gender group by the maximum average.

$$IGD = \frac{(\sum_{i=1}^n \text{average of each gender group} / n)}{\text{maximum average}} \quad (9)$$

Where n is the number of gender groups, and $0 < IGD \leq 1$. If $IGD = 1$, that means that the number of people in space for both gender groups at all times of the day is equal.

2.2.1.6 The intensity of stay (IS)

IS is calculated by dividing the average length of stay of individuals at all periods by the highest rate of stay. This study relies mainly on observing and monitoring people and their activities. Still, when we measured the duration of stay in space, we could not rely on observation. Consequently, the teams have been distributed at the entrances of the spaces. All who left the spaces have asked, "How long did you spend in space?". We record how long people stay in space during periods of the day, for a quarter of an hour each period, during weekdays. Then we calculated the average length of stay for each period, see Table 8.

$$\text{Average of each period of day} = \sum_{i=1}^m \text{people in the period} / m \quad (10)$$

Where m is the number of days.

We then calculated the (IS) by dividing the average of each period by the maximum.

$$IS = \frac{(\sum_{i=1}^n \text{average of each period} / n)}{\text{maximum average}} \quad (11)$$

Where n is the number of periods, and $0 < IS \leq 1$. If $IS = 1$, that means that the duration of people stay in space is the same at all times of the day

2.2.1.7 The intensity of activities (IA)

IA is calculated by dividing the average number of individuals for each type of activity by the highest rate. We counted the number of people practicing the three different activities in space (necessary, optional, and social activities), each activity separately, in all periods of the day, for a quarter of an hour in each period. Then we calculated the rate for each period, see Table 9.

$$\text{Average of each type of activity} = \sum_{i=1}^m \text{people in the type of activity} / m \quad (12)$$

Where m is the number of days

We then calculated the (IA) by dividing the average of all activities by the maximum value.

$$IA = \frac{(\sum_{i=1}^n \text{average of each type of activity} / n)}{\text{maximum average}} \quad (13)$$

Where n is the number of types of activities, and $0 < IA \leq 1$. If $IA = 1$, that means the people engage in different types of activities in space with the same intensity at all times of the day. In this variable, we could not differentiate between who walk as an optional or necessary activity in Al- Saleh Mosque square. Going daily for prayer in the mosque is often a necessary activity, but if the purpose is to visit the mosque and watch its architectural art, it may be considered as an optional activity. Therefore, to distinguish between the two goals, we considered only the number of people in space at Al-Fajer prayer time (05:00 a.m.) a necessary activity, and the rest as optional.

For the Intensity and Diversity of Use (IDU): We got the final score of the intensity and diversity of use through calculated of the average of the variables.

$$(IDU) = \sum_{i=1}^n (\text{average of all variables}) / n \quad (14)$$

Where n is the number of variables, and $0 < IDU \leq 1$. If $IDU = 1$, that means the certain space achieves an ideal level of diversity of use and users in all parts of the place and at all times of the day. Indicators Value ranges can be divided into three ranges, poor value when $IDU < 0$ to 0.35, Moderate when $IDU < 0.35$ to 0.70, and good when $IDU > 0.70$.

2.2.2 Determine the quality of public spaces by specialists

Previous studies reported multiple methods of measuring public spaces' quality and success, such as user satisfaction and experiences, direct observation, expert and specialist evaluations, and monitoring and recording user behaviour. The study determines the quality of public spaces in this part through evaluations of architects and urban designers of the state of specific spaces. Based on

a comprehensive review of the theoretical and empirical literature on the quality of public open spaces, the study deals with the quality of public spaces from four aspects: the quality of the physical settings for the activities' facilities, the quality of the atmosphere, the visual quality, and the meanings and cultural values. Through a comprehensive review of previous studies that dealt with the quality of public spaces, 43 items were identified to measure the quality of public space and then distributed on the four specific aspects, see Table 2.

A draft questionnaire was presented to seven urban design and planning experts to determine the Content Validity Index (CVI). They were asked to determine how the items relate to the factors and how they relate to the questionnaire's main concept. The extent of the correlation is determined by seven Likert scales, where one is irrelevant, and 7 is completely related. Table 2 indicates the results of content validity indicators. Most of the items achieved valid marks except two items whose marks were less than 0.78, as studies indicate that items whose scores in the content validity index are less than 0.78 are invalid [82], [83]. Therefore, the two items were excluded, and the number of items became 41 items.

In May 2020, the pilot study was conducted by sending the developed questionnaire to 30 architects and urban designers to assess the quality of specific public spaces. The study used the five-point Likert scale to determine the extent to which the studied spaces achieve the items and factors that measure the quality of spaces, as 1 is unverified, and 5 is fully achieved. The study used the (alpha) Cronbach's Coefficient to check the internal consistency of the questionnaire as it is a famous and widely used method of verifying reliability [84-86]. Results showed a high level of internal consistency in questionnaire items (0.717, 0.688, 7.04, and 0.744).

In July 2020, the final version of the questionnaire was sent to more than 200 architects and urban designers who live in Sana'a city via e-mails and social media sites. They were asked to assess the condition of the specified spaces. About 161 valid questionnaires were obtained. The study also used the (alpha) Cronbach's Coefficient to check the internal consistency of the questionnaire. Results showed a high level of internal consistency in questionnaire items (0.962, 0.943, 0.886 and 0.971).

Table 2. Content validity index for items of measurement tool by Experts.

| Codes | Factors | Items | F-CVI | M-CVI | |
|-------|---|---|---|-------|------|
| PH1 | physical settings of activities' facilities | seating areas | Adequate and various | 0.98 | 1.00 |
| PH2 | | | Encourage social interaction | 0.85 | 0.92 |
| PH3 | | | overlooks the landscape and the activities of others | 0.90 | 0.90 |
| PH4 | | walking paths | Connecting all regions of space | 0.93 | 0.95 |
| PH5 | | | Provide long walking trails | 0.87 | 0.88 |
| PH6 | | Children's playgrounds | Varied and sufficient | 0.97 | 0.95 |
| PH7 | | | Safe surfaces, suitable for children | 1.00 | 1.00 |
| PH8 | | | Surrounded by observation seating areas | 0.97 | 0.97 |
| PH9 | | Teens and youth play | Varied and sufficient | 0.97 | 0.95 |
| PH10 | | | Modern and updated | 1.00 | 0.98 |
| PH11 | | Sports and physical activities | Various sports fields | 0.85 | 0.82 |
| PH12 | | | Sufficient and varied physical activity equipment | 0.82 | 0.85 |
| PH13 | | Suitable supporting facilities | Restaurants and cafes | 0.78 | 0.80 |
| PH14 | | | Toilets | 0.78 | 0.78 |
| PH15 | | | Seats and dining tables | 0.80 | 0.83 |
| - | | | Signboards | 0.75 | 0.67 |
| PH16 | | | Litter bins | 0.78 | 0.80 |
| PH17 | | | Parking | 0.78 | 0.78 |
| PH18 | | Other related settings | Space size | 0.92 | 0.93 |
| PH19 | | | Integration of facilities and activities | 0.98 | 1.00 |
| PH20 | | | Use of information technology for multiple purposes. | 0.90 | 0.92 |
| PH21 | | | Provision emergency stations and surveillance cameras | 0.78 | 0.78 |
| PH22 | Pedestrian movement separated from traffic | | 0.85 | 0.87 | |
| M | - | | - | 0.92 | - |
| QA1 | Quality of the atmosphere | various green elements and areas | 0.95 | 0.95 | |
| QA2 | | various of Water features | 0.87 | 0.90 | |
| QA3 | | Activity areas are protected from natural conditions | 0.90 | 0.92 | |
| QA4 | | well-maintenance and cleanliness of equipment and surfaces | 0.98 | 1.00 | |
| QA5 | | Suitable lighting | 0.97 | 0.95 | |
| QA6 | | Air purity from dust and pollutants | 0.95 | 0.93 | |
| QA7 | | Quiet, nature sounds, and noise-free | 0.90 | 0.87 | |
| QA8 | | Being Free from annoying people or annoying behaviors | 0.78 | 0.87 | |
| M | - | - | 0.91 | - | |
| VQ1 | 3D visual quality | variety of Landscape elements | 0.95 | 0.95 | |
| VQ2 | | Variety of Hardscape elements | 0.90 | 0.90 | |
| VQ3 | | Unity in the shape, color, and size of elements | 0.92 | 0.90 | |
| - | | The complexity of two-dimensional composition | 0.67 | 0.60 | |
| VQ4 | | visibility and transparency of the space parts | 0.88 | 0.80 | |
| VQ5 | | The human visual scale in the dimensions of the elements | 0.90 | 0.80 | |
| VQ6 | | Being free from visual pollution elements | 0.95 | 0.90 | |
| VQ7 | | The consistency of the visual landscape images with the surrounding environment | 0.90 | 0.85 | |
| M | - | - | 0.91 | - | |
| MC1 | Meanings and Culture values | Distinctive and unique design | 0.95 | 0.93 | |
| MC2 | | Historical and cultural elements | 0.97 | 0.88 | |
| MC3 | | Unique, memorable, distinctive elements and landmarks | 0.90 | 0.82 | |
| MC4 | | The space design is so complex evoking the sense of discovery. | 0.80 | 0.78 | |
| M | | - | - | 0.90 | - |
| M | - | - | - | 0.89 | |

2.2.3 Determine the correlation between IDU and QPS

The study aims to develop a tool to measure the intensity and diversity of use based on the META method 2007 by adding the spatial dimension and using the temporal dimension widely. In order to also support the adequacy of the tool developed in this study, correlation coefficients are determined between the results of the developed tool and the results of the quality of the selected spaces. Pearson's Correlation Coefficient is used to measure the relationship between two random

variables [87], because it is the preferred measure for linear variables and parameters [88]. Therefore, the Pearson’s Coefficient was used to determine the relationships between the DSU and the characteristics and quality of the studied spaces. Table 11 shows the Pearson’s Coefficients r and the p values for all items.

3. Results

3.1. Results of IDU and QPS

In general, the intensity and diversity of use (IDU) for both Al-Sabeen and Al-Thawra Parks (0.79, and 0.72) is higher than the intensity of use and diversity for both Al-Tahrir and Al-Saleh Mosque Squares (0.58 and 0.54), (see Table 3), and (Figure 2). The intensity of temporal use is high in Al-Tahrir Square (0.87), while it is moderate in the rest of the selected spaces (0.68, 0.63, 0.64), (see Table 4). The intensity of spatial use is high in Al-Sabeen Park (0.92), but poor in both Al-Tahrir and Al-Saleh Mosque Squares (0.46, 0.40) and Al-Thawra Parks (0.38), (see Table 5). The intensity of social use is high in both Al-Sabeen and Al-Thawra Parks (0.81, and 0.80), moderate in Al-Saleh Mosque Square (0.57), and poor in Al-Tahrir Square (0.33), (see Table 6). The intensity of age diversity is high in both Al-Sabeen and Al-Thawra Parks (0.71, and 0.72), and moderate in both of Al-Tahrir and Al-Saleh Mosque Squares (0.56, and 0.52), (see Table 7).

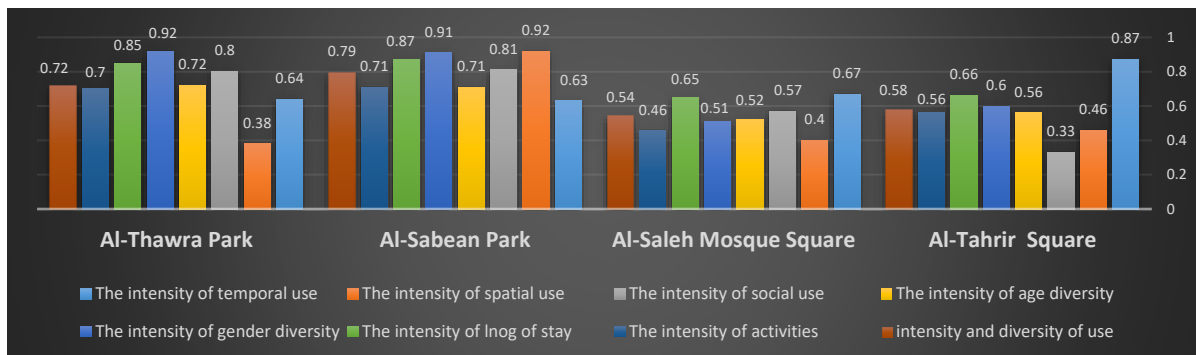


Figure 2. The intensity and diversity of use of four selected spaces

At the same, the intensity of gender diversity is high in both Al-Sabeen and Al-Thawra Parks (0.91, and 0.92), and moderate in both of Al-Tahrir and Al-Saleh Mosque Squares (0.60, and 0.51), (see Table 7). Also, the intensity of stay is high in both Al-Sabeen and Al-Thawra Parks (0.87, and 0.85), and moderate in both of Al-Tahrir and Al-Saleh Mosque Squares (0.66, and 0.65), (see Table 8). The intensity of activities is good in both Al-Sabeen and Al-Thawra Parks (0.71 and 0.70),

moderate in Al- Tahrir Square (0.56), and poor in Al-Saleh Mosque Square (0.46), (see Table 9).

The results also show the stay rate in space, which is not related to the tool of intensity and diversity of use, but is an important indicator of space performance. The afternoon is the most occupied period in specific spaces. The highest rate of stay was in Al-Sabean Park (161) minutes. Followed by Al-Thawra Park (160.29) minutes and then Al-Saleh Mosque Square (158) minutes and Al Tahrir Park (131) minutes. *Note “The values in the tables 5-10 are the sum of people in the day periods (morning, noon, afternoon and evening),15 minutes per period”.*

Table 3. The intensity and diversity of use of four selected spaces

| The indicators | Al-Tahrir Square | Al-Saleh Mosque Square | Al-Sabean Park | Al-Thawra Park |
|--------------------------------------|------------------|------------------------|----------------|----------------|
| The intensity of temporal use | 0.87 | 0.68 | 0.63 | 0.64 |
| The intensity of spatial use | 0.46 | 0.40 | 0.92 | 0.38 |
| The intensity of social use | 0.33 | 0.57 | 0.81 | 0.80 |
| The intensity of age diversity | 0.56 | 0.52 | 0.71 | 0.72 |
| The intensity of gender diversity | 0.60 | 0.51 | 0.91 | 0.92 |
| The intensity of stay | 0.66 | 0.65 | 0.87 | 0.85 |
| The intensity of activities | 0.56 | 0.46 | 0.71 | 0.70 |
| Intensity and diversity of use (IDU) | 0.58 | 0.54 | 0.79 | 0.72 |

Table 4. The intensity of temporal use of four selected spaces

| Periods | Days | Al-Tahrir Square | Al-Saleh Mosque Square | Al-Sabean Park | Al-Thawra Park |
|-------------------------------|----------|------------------|------------------------|----------------|----------------|
| Morning | workdays | 162 | 44 | 319 | 187 |
| | | 178 | 53 | 328 | 292 |
| | | 103 | 59 | 274 | 236 |
| | | 168 | 41 | 293 | 194 |
| | | 164 | 49 | 322 | 287 |
| | weekends | 105 | 47 | 211 | 262 |
| | | 117 | 59 | 307 | 295 |
| m | 142.43 | 50.29 | 293.43 | 250.43 | |
| At Noon | workdays | 129 | 267 | 388 | 418 |
| | | 113 | 254 | 555 | 480 |
| | | 127 | 248 | 485 | 392 |
| | | 164 | 237 | 491 | 423 |
| | | 136 | 276 | 528 | 406 |
| | weekends | 61 | 289 | 293 | 513 |
| | | 73 | 848 | 388 | 479 |
| m | 114.71 | 345.57 | 446.86 | 444.43 | |
| Afternoon | workdays | 179 | 436 | 1324 | 1275 |
| | | 162 | 468 | 1567 | 1232 |
| | | 187 | 455 | 1423 | 1187 |
| | | 163 | 429 | 1474 | 1248 |
| | | 172 | 472 | 1553 | 1261 |
| | weekends | 182 | 434 | 1123 | 1197 |
| | | 156 | 1125 | 1298 | 1224 |
| m | 171.57 | 545.57 | 1394.57 | 1232.00 | |
| Evening | workdays | 82 | 273 | 288 | 192 |
| | | 65 | 296 | 316 | 281 |
| | | 77 | 267 | 307 | 198 |
| | | 95 | 287 | 290 | 264 |
| | | 58 | 281 | 322 | 332 |
| | weekends | 33 | 297 | 950 | 469 |
| | | 48 | 425 | 488 | 418 |
| m | 65.43 | 303.71 | 423.00 | 307.71 | |
| The highest number | | 171.57 | 545.57 | 1394.57 | 1232.00 |
| Arithmetic mean | | 150.07 | 371.75 | 882.36 | 789.71 |
| The intensity of temporal use | | 0.87 | 0.68 | 0.63 | 0.64 |

Table 5. The intensity of spatial use of four selected spaces

| Zones | Days | Al-Tahrir Square | Al-Saleh Mosque Square | Al-Sabeen Park | Al-Thawra Park |
|------------------------------|----------|------------------|------------------------|----------------|----------------|
| A | workdays | 43 | 831 | 499 | 91 |
| | | 66 | 876 | 690 | 218 |
| | | 59 | 917 | 513 | 196 |
| | | 47 | 968 | 582 | 107 |
| | weekends | 58 | 881 | 691 | 181 |
| | | 22 | 912 | 612 | 133 |
| | m | 18 | 1464 | 577 | 124 |
| | | 44.71 | 978.43 | 594.86 | 150.00 |
| B | workdays | 110 | 146 | 622 | 78 |
| | | 127 | 138 | 823 | 94 |
| | | 113 | 187 | 766 | 106 |
| | | 126 | 125 | 689 | 183 |
| | weekends | 107 | 81 | 712 | 198 |
| | | 114 | 142 | 501 | 141 |
| | m | 131 | 206 | 482 | 132 |
| | | 118.29 | 146.43 | 656.43 | 133.14 |
| C | workdays | 37 | 41 | 493 | 244 |
| | | 68 | 43 | 848 | 217 |
| | | 44 | 36 | 671 | 166 |
| | | 56 | 42 | 583 | 239 |
| | weekends | 62 | 53 | 713 | 181 |
| | | 33 | 57 | 630 | 217 |
| | m | 39 | 62 | 791 | 204 |
| | | 48.43 | 47.71 | 675.57 | 209.71 |
| D | workdays | 337 | - | 678 | 344 |
| | | 208 | - | 325 | 326 |
| | | 310 | - | 466 | 288 |
| | | 256 | - | 582 | 352 |
| | weekends | 275 | - | 594 | 339 |
| | | 164 | - | 667 | 296 |
| | m | 173 | - | 683 | 316 |
| | | 246.14 | - | 570.71 | 323.00 |
| E | workdays | - | - | - | 219 |
| | | - | - | - | 50 |
| | | - | - | - | 157 |
| | | - | - | - | 134 |
| | weekends | - | - | - | 211 |
| | | - | - | - | 278 |
| | m | - | - | - | 264 |
| | | - | - | - | 187.57 |
| F | workdays | - | - | - | 635 |
| | | - | - | - | 690 |
| | | - | - | - | 718 |
| | | - | - | - | 582 |
| | weekends | - | - | - | 661 |
| | | - | - | - | 1017 |
| | m | - | - | - | 984 |
| | | - | - | - | 755.29 |
| G | workdays | - | - | - | 298 |
| | | - | - | - | 163 |
| | | - | - | - | 254 |
| | | - | - | - | 172 |
| | weekends | - | - | - | 244 |
| | | - | - | - | 251 |
| | m | - | - | - | 247 |
| | | - | - | - | 232.71 |
| Highest number | | 246.14 | 978.43 | 675.57 | 755.29 |
| Arithmetic mean | | 114.39 | 390.86 | 624.39 | 284.49 |
| The intensity of spatial use | | 0.46 | 0.40 | 0.92 | 0.38 |

Table 6. The intensity of social use of four selected spaces

| Public spaces | People and intensity | Workdays | | | | | Weekends | | Mean |
|------------------------|----------------------------|----------|------|------|------|------|----------|------|------|
| Al-Tahrir Square | Number of people as groups | 77 | 260 | 184 | 94 | 157 | 90 | 102 | - |
| | Total | 424 | 580 | 423 | 416 | 355 | 327 | 373 | - |
| | intensity of social use | 0.18 | 0.45 | 0.43 | 0.23 | 0.44 | 0.28 | 0.27 | 0.33 |
| Al-Saleh Mosque Square | Number of people as groups | 632 | 576 | 537 | 491 | 486 | 586 | 1083 | - |
| | Total | 1052 | 1036 | 994 | 856 | 982 | 1011 | 1680 | - |
| | intensity of social use | 0.60 | 0.56 | 0.54 | 0.57 | 0.49 | 0.58 | 0.65 | 0.57 |
| Al-Sabeen Park | Number of people as groups | 1983 | 1722 | 1764 | 1832 | 1978 | 1699 | 1593 | - |
| | Total | 2190 | 2083 | 2134 | 2203 | 2464 | 2319 | 2245 | - |
| | intensity of social use | 0.91 | 0.83 | 0.83 | 0.83 | 0.80 | 0.73 | 0.71 | 0.81 |
| Al-Thawra Park | Number of people as groups | 1554 | 1626 | 1576 | 1489 | 1564 | 1445 | 2011 | - |
| | Total | 1905 | 1977 | 1982 | 1906 | 2006 | 1994 | 2333 | - |
| | intensity of social use | 0.82 | 0.82 | 0.80 | 0.78 | 0.78 | 0.72 | 0.86 | 0.80 |

3.1. Results of correlation between IDU and QPS

Results generally indicate a correlation between the IDU index in the specified spaces and the quality index of these spaces. The Pearson’s Correlation Coefficient is ($r=0.999$, $P=0.035$) (see Table 11). Although Al-Saleh Mosque Square has achieved a high mark in the space quality index, its mark in the IDU index is not high due to laws that prevent women from accessing the square during weekdays and the lack of suitable places to sit. Therefore, we excluded the results of Al-Saleh Mosque Square when computing the Pearson’s Correlation Coefficients due to their negative impact on the results. Results indicate a statistically significant correlation between the IDU index and the score of quality of the physical settings for the activities' facilities ($r=0.998$, $P=0.045$). A group of sub-items have statistically significant associations, which are the quality of the settings for activities of the sitting ($r=0.999$, $P=0.013$), walking ($r=0.999$, $P=0.027$), children's play ($r=0.999$, $P=0.028$), youth and adolescent play ($r=0.997$, $P=0.045$), some settings supporting recreational activities such as tables and chairs ($r=0.999$, $P=0.030$), litter boxes ($r=0.999$, $P=0.024$), and parking ($r=0.999$, $P=0.024$). The IDU has been linked to some other settings, which are the size of the space ($r=0.997$, $P=0.048$), the integration and overlap of activities and facilities ($r=0.997$, $P=0.037$), and the separation of pedestrian traffic from the movement of vehicles ($r=0.999$, $P=0.033$). Although the results did not indicate the correlation of the IDU index with the factors of the quality of the atmosphere and visual quality, they indicate that there are statistically significant correlations for some items with the IDU, namely the diversity of elements and natural spaces ($r=0.999$, $P=0.030$), well-maintenance and cleanliness of equipment and surfaces ($r=0.999$, $P=0.029$), the protection of different activities areas from natural conditions ($r=0.999$, $P=0.021$), the absence of space from intruders and disturbing behaviors ($r=0.999$, $P=0.013$), diversity of natural elements ($r=0.999$, $P=0.021$), and variety of hardscape elements ($r=0.998$, $P=0.042$).

Table 7. The intensity of age diversity and gender diversity of four selected spaces

| Ages | Days | Al-Tahrir Square | | | Al-Saleh Mosque Square | | | Al-Sabeen Park | | | Al-Thawra Park | | |
|--------------------------------|-------------|------------------|-------------|-------------|------------------------|-------------|-------------|----------------|-------------|-------------|----------------|-------------|-------|
| | | M | F | Total | M | F | Total | M | F | Total | M | F | Total |
| 0-5 | workdays | 10 | 5 | 15 | 0 | 0 | 0 | 135 | 160 | 295 | 89 | 113 | 202 |
| | | 13 | 5 | 18 | 0 | 0 | 0 | 181 | 223 | 404 | 122 | 171 | 293 |
| | | 14 | 7 | 21 | 2 | 0 | 2 | 166 | 201 | 367 | 113 | 142 | 255 |
| | | 19 | 3 | 22 | 0 | 1 | 1 | 151 | 163 | 314 | 78 | 126 | 204 |
| | weekends | 9 | 8 | 17 | 0 | 0 | 0 | 172 | 184 | 356 | 132 | 117 | 249 |
| | | 6 | 2 | 8 | 1 | 0 | 1 | 102 | 116 | 218 | 110 | 121 | 231 |
| | sum | 13 | 6 | 19 | 1 | 0 | 1 | 114 | 123 | 237 | 93 | 134 | 227 |
| | m | 84 | 36 | 120 | 4 | 1 | 5 | 1021 | 1170 | 2191 | 737 | 924 | 1661 |
| | 12.0 | 5.1 | 17.1 | 0.6 | 0.1 | 0.7 | 145.9 | 167.1 | 313.0 | 105.3 | 132.0 | 237.3 | |
| 6--12 | workdays | 32 | 8 | 40 | 174 | 9 | 183 | 238 | 254 | 492 | 193 | 201 | 394 |
| | | 76 | 29 | 105 | 136 | 17 | 153 | 288 | 324 | 612 | 233 | 218 | 451 |
| | | 57 | 22 | 79 | 154 | 21 | 175 | 276 | 263 | 539 | 226 | 216 | 442 |
| | | 64 | 19 | 83 | 168 | 8 | 176 | 261 | 306 | 567 | 193 | 207 | 400 |
| | | 62 | 13 | 75 | 149 | 15 | 164 | 248 | 287 | 535 | 210 | 185 | 395 |
| | weekends | 48 | 11 | 59 | 287 | 24 | 311 | 303 | 341 | 644 | 245 | 291 | 536 |
| | | 53 | 18 | 71 | 264 | 31 | 295 | 281 | 302 | 583 | 231 | 226 | 457 |
| | sum | 392 | 120 | 512 | 1332 | 125 | 1457 | 1895 | 2077 | 3972 | 1531 | 1544 | 3075 |
| m | 56.0 | 17.1 | 73.1 | 190.3 | 17.9 | 208.1 | 270.7 | 296.7 | 567.4 | 218.7 | 220.6 | 439.3 | |
| 13-18 | workdays | 83 | 10 | 93 | 329 | 1 | 330 | 213 | 185 | 398 | 143 | 176 | 319 |
| | | 97 | 12 | 109 | 307 | 3 | 310 | 260 | 232 | 492 | 120 | 180 | 300 |
| | | 88 | 13 | 101 | 323 | 5 | 328 | 235 | 228 | 463 | 132 | 193 | 325 |
| | | 103 | 11 | 114 | 289 | 0 | 289 | 249 | 169 | 418 | 151 | 168 | 319 |
| | | 79 | 8 | 87 | 332 | 2 | 334 | 209 | 201 | 410 | 133 | 182 | 315 |
| | weekends | 63 | 6 | 69 | 341 | 12 | 353 | 126 | 122 | 248 | 230 | 203 | 433 |
| | | 85 | 9 | 94 | 374 | 19 | 393 | 117 | 131 | 248 | 218 | 212 | 430 |
| | sum | 598 | 69 | 667 | 2295 | 42 | 2337 | 1409 | 1268 | 2677 | 1127 | 1314 | 2441 |
| m | 85.4 | 9.9 | 95.3 | 327.9 | 6.00 | 333.9 | 201.3 | 181.1 | 382.4 | 161.0 | 187.7 | 348.7 | |
| 19-29 | workdays | 103 | 17 | 120 | 260 | 2 | 262 | 190 | 202 | 392 | 165 | 181 | 346 |
| | | 94 | 15 | 109 | 242 | 4 | 246 | 253 | 426 | 679 | 150 | 226 | 376 |
| | | 98 | 16 | 114 | 254 | 3 | 257 | 247 | 329 | 576 | 136 | 192 | 328 |
| | | 106 | 18 | 124 | 261 | 6 | 267 | 223 | 341 | 564 | 162 | 218 | 380 |
| | | 84 | 11 | 95 | 216 | 2 | 218 | 238 | 296 | 534 | 159 | 207 | 366 |
| | weekends | 61 | 8 | 69 | 307 | 4 | 311 | 106 | 462 | 568 | 186 | 211 | 397 |
| | | 81 | 14 | 95 | 752 | 27 | 779 | 178 | 384 | 562 | 178 | 221 | 399 |
| | sum | 627 | 99 | 726 | 2292 | 48 | 2340 | 1435 | 2440 | 3875 | 1136 | 1456 | 2592 |
| m | 89.6 | 14.1 | 103.7 | 327.4 | 6.86 | 334.3 | 205.0 | 348.6 | 553.6 | 162.3 | 208.0 | 370.3 | |
| 30-45 | workdays | 118 | 15 | 133 | 541 | 9 | 550 | 219 | 365 | 584 | 227 | 249 | 476 |
| | | 135 | 37 | 172 | 359 | 11 | 370 | 208 | 161 | 369 | 166 | 268 | 434 |
| | | 126 | 33 | 159 | 423 | 7 | 430 | 194 | 247 | 441 | 217 | 255 | 472 |
| | | 131 | 29 | 160 | 471 | 1 | 472 | 221 | 276 | 497 | 201 | 238 | 439 |
| | | 117 | 26 | 143 | 382 | 2 | 384 | 243 | 291 | 534 | 212 | 274 | 486 |
| | weekends | 98 | 16 | 114 | 459 | 4 | 463 | 206 | 320 | 526 | 258 | 298 | 556 |
| | | 112 | 12 | 124 | 459 | 12 | 471 | 186 | 238 | 424 | 231 | 252 | 483 |
| | sum | 837 | 168 | 1005 | 3094 | 46 | 3140 | 1477 | 1898 | 3375 | 1512 | 1834 | 3346 |
| m | 119.6 | 24.0 | 143.6 | 442.0 | 6.6 | 448.0 | 211.0 | 271.1 | 482.1 | 216.0 | 262.0 | 478.0 | |
| older than 45 | workdays | 32 | 1 | 33 | 58 | 0 | 58 | 28 | 39 | 67 | 90 | 120 | 210 |
| | | 57 | 13 | 70 | 39 | 0 | 39 | 86 | 88 | 174 | 50 | 71 | 121 |
| | | 48 | 21 | 69 | 47 | 2 | 49 | 55 | 72 | 127 | 62 | 88 | 150 |
| | | 54 | 17 | 71 | 61 | 0 | 61 | 61 | 53 | 114 | 74 | 123 | 197 |
| | | 59 | 11 | 70 | 43 | 0 | 43 | 32 | 51 | 83 | 53 | 66 | 119 |
| | weekends | 10 | 3 | 13 | 63 | 1 | 64 | 48 | 79 | 127 | 94 | 190 | 284 |
| | | 16 | 4 | 20 | 140 | 5 | 145 | 34 | 52 | 86 | 87 | 153 | 240 |
| | sum | 276 | 70 | 346 | 451 | 8 | 459 | 344 | 434 | 778 | 510 | 811 | 1321 |
| m | 39.4 | 10.0 | 49.4 | 64.4 | 1.1 | 65.6 | 49.1 | 62.0 | 111.1 | 72.9 | 115.9 | 188.7 | |
| highest number | - | - | 143.6 | - | - | 448.6 | - | - | 567.4 | - | - | 478.0 | |
| Arithmetic mean | - | - | 80.4 | - | - | 231.9 | - | - | 401.6 | - | - | 343.7 | |
| The intensity of age diversity | - | - | 0.56 | - | - | 0.52 | - | - | 0.71 | - | - | 0.72 | |
| Total | 2814 | 562 | - | 9468 | 270 | - | 7581 | 9287 | - | 6553 | 7883 | - | |
| Arithmetic mean | 1688 | - | - | 4869 | - | - | 8434 | - | - | 7218 | - | - | |
| Gender diversity | 0.60 | - | - | 0.51 | - | - | 0.91 | - | - | 0.92 | - | - | |

Table 8. The intensity of stay of four selected spaces

| Periods | Days | Al-Tahrir Square | Al-Saleh Mosque Square | Al-Sabean Park | Al-Thawra Park |
|---------------------------|----------|------------------|------------------------|----------------|----------------|
| Morning | workdays | 35 | 38 | 153 | 182 |
| | | 42 | 48 | 146 | 138 |
| | | 53 | 42 | 161 | 145 |
| | | 38 | 34 | 143 | 94 |
| | | 31 | 45 | 136 | 136 |
| | weekends | 54 | 42 | 142 | 154 |
| | | 47 | 36 | 151 | 147 |
| m | 42.86 | 40.71 | 147.43 | 142.29 | |
| At Noon | workdays | 47 | 54 | 98 | 85 |
| | | 41 | 58 | 85 | 76 |
| | | 52 | 49 | 89 | 83 |
| | | 36 | 62 | 93 | 91 |
| | | 44 | 56 | 84 | 80 |
| | weekends | 39 | 53 | 86 | 87 |
| | | 47 | 48 | 91 | 94 |
| m | 43.71 | 54.29 | 89.43 | 85.14 | |
| Afternoon | workdays | 142 | 134 | 161 | 145 |
| | | 129 | 159 | 146 | 187 |
| | | 138 | 146 | 132 | 166 |
| | | 126 | 152 | 177 | 154 |
| | | 131 | 149 | 161 | 187 |
| | weekends | 125 | 176 | 186 | 145 |
| | | 132 | 194 | 164 | 138 |
| m | 131.86 | 158.57 | 161.00 | 160.29 | |
| Evening | workdays | 43 | 36 | 87 | 77 |
| | | 37 | 43 | 94 | 93 |
| | | 44 | 34 | 91 | 58 |
| | | 41 | 41 | 102 | 72 |
| | | 31 | 36 | 89 | 64 |
| | weekends | 25 | 45 | 88 | 61 |
| | | 32 | 38 | 97 | 68 |
| m | 36.14 | 39.00 | 92.57 | 70.43 | |
| highest number | | 131.86 | 158.57 | 161.00 | 160.29 |
| Arithmetic mean | | 87.57 | 103.04 | 139.71 | 137.00 |
| Intensity of temporal use | | 0.66 | 0.65 | 0.87 | 0.85 |

Table 9. The intensity of activities of four selected spaces

| Activities | Days | Al-Tahrir Square | Al-Saleh Mosque Square | Al-Sabean Park | Al-Thawra Park |
|-----------------------------|----------|------------------|------------------------|----------------|----------------|
| Necessary activities | workdays | 315 | 87 | - | - |
| | | 467 | 91 | - | - |
| | | 376 | 74 | - | - |
| | | 332 | 82 | - | - |
| | | 396 | 77 | - | - |
| | weekends | 126 | 91 | - | - |
| | | 107 | 194 | - | - |
| m | 302.71 | 99.43 | - | - | |
| optional activities | workdays | 108 | 897 | 571 | 564 |
| | | 119 | 768 | 753 | 451 |
| | | 112 | 543 | 683 | 588 |
| | | 108 | 612 | 634 | 517 |
| | | 123 | 834 | 795 | 543 |
| | weekends | 109 | 781 | 582 | 645 |
| | | 87 | 1632 | 632 | 604 |
| m | 109.43 | 866.71 | 664.29 | 558.86 | |
| Social activities | workdays | 107 | 273 | 1406 | 1262 |
| | | 90 | 291 | 1682 | 1359 |
| | | 76 | 287 | 1538 | 1411 |
| | | 109 | 241 | 1611 | 1389 |
| | | 114 | 265 | 1598 | 1423 |
| | weekends | 123 | 213 | 1604 | 1568 |
| | | 86 | 101 | 1628 | 1406 |
| m | 100.71 | 238.71 | 1581.00 | 1402.57 | |
| Highest number | | 302.71 | 866.71 | 1581.00 | 1402.57 |
| Arithmetic mean | | 170.95 | 401.62 | 1122.64 | 980.71 |
| The intensity of activities | | 0.56 | 0.46 | 0.71 | 0.70 |

On the other hand, Table 10. reveals results of the quality index of specific spaces. The results indicate the preference for Al Saleh Mosque Square and Al-Sabeen Park over Al-Tahrir Square and Al-Thawra Park in the Index of Space Quality.

Table 10. Quality of selected public spaces.

| Factors | | Codes | Al-Tahrir Square | Al-Saleh Mosque Square | Al-Sabeen Park | Al-Thawra Park |
|---|--------------------------------|-------|------------------|------------------------|----------------|----------------|
| physical settings of activities' facilities | seating areas | PH1 | 2.18 | 2.37 | 3.36 | 2.89 |
| | | PH2 | 2.43 | 2.19 | 3.15 | 2.93 |
| | | PH3 | 2.45 | 2.73 | 3.29 | 2.98 |
| | walking paths | M | 2.35 | 2.43 | 3.26 | 2.93 |
| | | PH4 | 3.16 | 3.85 | 4.15 | 3.81 |
| | | PH5 | 1.65 | 4.04 | 4.01 | 4.06 |
| | Children's playgrounds | M | 2.41 | 3.94 | 4.08 | 3.93 |
| | | PH6 | - | - | 3.24 | 2.30 |
| | | PH7 | - | - | 2.73 | 2.44 |
| | | PH8 | - | - | 2.92 | 2.32 |
| | Teens and youth play | M | - | - | 2.96 | 2.35 |
| | | PH9 | - | - | 2.00 | 1.74 |
| | | PH10 | - | - | 1.87 | 1.48 |
| | Sports and physical activities | M | - | - | 1.94 | 1.61 |
| | | PH11 | - | - | 1.89 | 1.81 |
| | | PH12 | - | - | 1.55 | 1.51 |
| | Suitable supporting facilities | M | - | - | 1.72 | 1.66 |
| | | PH13 | 2.76 | 1.30 | 2.04 | 2.01 |
| | | PH14 | 1.87 | 3.60 | 2.33 | 2.22 |
| | | PH15 | 1.63 | 1.29 | 2.86 | 2.34 |
| | | PH16 | 1.86 | 3.37 | 2.90 | 2.47 |
| | | PH17 | 2.67 | 4.13 | 4.29 | 3.62 |
| Other related settings | M | 2.16 | 2.74 | 2.88 | 2.53 | |
| | PH18 | 1.83 | 4.41 | 4.62 | 3.75 | |
| | PH19 | 2.16 | 2.57 | 3.84 | 3.09 | |
| | PH20 | 1.19 | 1.39 | 1.19 | 1.23 | |
| | PH21 | 1.33 | 3.68 | 2.11 | 2.45 | |
| M | PH22 | 1.85 | 2.84 | 3.91 | 3.22 | |
| | M | 1.67 | 2.98 | 3.13 | 2.75 | |
| M | | | 2.15 | 3.02 | 2.85 | 2.54 |
| Quality of the atmosphere | QA1 | 2.04 | 3.11 | 3.65 | 2.97 | |
| | QA2 | 1.53 | 1.72 | 2.08 | 2.00 | |
| | QA3 | 2.13 | 1.56 | 3.45 | 3.00 | |
| | QA4 | 1.80 | 3.52 | 2.97 | 2.49 | |
| | QA5 | 2.14 | 3.15 | 2.95 | 2.41 | |
| | QA6 | 2.23 | 2.85 | 2.73 | 2.78 | |
| | QA7 | 1.44 | 3.36 | 2.93 | 2.96 | |
| | QA8 | 2.24 | 3.30 | 3.13 | 2.77 | |
| | M | 1.94 | 2.82 | 2.99 | 2.67 | |
| 3D visual quality | VQ1 | 2.17 | 2.91 | 3.22 | 2.79 | |
| | VQ2 | 1.94 | 2.85 | 2.92 | 2.49 | |
| | VQ3 | 2.85 | 3.60 | 2.76 | 2.59 | |
| | VQ4 | 3.32 | 3.95 | 3.78 | 4.31 | |
| | VQ5 | 3.56 | 3.11 | 3.68 | 3.71 | |
| | VQ6 | 2.06 | 3.73 | 2.63 | 2.33 | |
| | VQ7 | 2.47 | 3.35 | 2.85 | 2.99 | |
| | M | 2.62 | 3.36 | 3.12 | 3.03 | |
| Meanings and values | MC1 | 1.85 | 3.97 | 3.61 | 2.39 | |
| | MC2 | 2.52 | 3.57 | 2.33 | 2.59 | |
| | MC3 | 2.79 | 4.25 | 2.84 | 2.69 | |
| | MC4 | 2.58 | 3.19 | 3.46 | 2.54 | |
| | M | 2.43 | 3.75 | 3.06 | 2.55 | |
| QPS | | | 9.15 | 12.95 | 12.02 | 10.79 |

4. Discussion

In this study, we attempt to develop Mehta [34] methodology to become more comprehensive. We argue about the addition of the spatial dimension and the use of the time dimension extensively, when measuring the intensity and diversity of the use of public open spaces. Although Eriawan and Setiawati (2017)[89], Eriawan (2017)[90], Siregar (2014) [91], and Parlindungan (2013) [92] have used this methodology to evaluate public spaces, they have not addressed the intensity of spatial use. Moreover, this study also proves that the IDU index is related to the index of QPS. The study measured the quality of public spaces by surveying the opinions of specialists from architects and urban designers, and the results in Table 11 indicate a direct correlation between the IDU index and the QPS index.

The results of the study indicate that the high diversity of usage and users in public spaces is positively related to a set of physical settings and administrative procedures. Consistent with the results of this study, a group of studies indicate that the intensity of use and users in public spaces may positively correlate with a set of public space characteristics such as the availability of adequate and comfortable seating areas [25], [26], [39], the efficiency of pedestrian paths [40-42], diversity and efficiency of play facilities for children and adolescents [15], [26], [44], [55], settings that support recreational activities, such as the availability of seats and dining tables [52], [53], the size of the space [55], the integration of the activities and facilities [19], the separation of pedestrian movement from the movement of vehicles [53], [56], the diversity of landscape and hardscape elements [35], [56], well-maintenance and cleanliness of equipment and surfaces [63], [64], [71], [93], the protection from natural conditions [61], and the absence of the space from intruders and annoying behaviors [53], [67]. Therefore, agreement of the reports of this study with a group of the signals of previous studies may represent additional support for the tool developed in this study to measure the quality of public spaces.

In contrast with the results of this study, many previous studies have indicated a correlation between public space use with facilities of sports and physical activities[16], [46], [94]. Still, the results of this study agree with the results of [95] study, which indicated that Yemenis perceive public space differently. Sports and physical activities are not major reasons for visiting public spaces in Sana'a city and Yemen.

Table 11. Pearson’s Correlation Coefficients between the IDU and QPS

| Factors | | IDU | Pearson’s Correlation (<i>r</i>) | <i>P</i> -Value |
|---|--------------------------------|--------|------------------------------------|-----------------|
| physical settings of activities’ facilities | seating areas | PH1 | 0.999* | 0.013 |
| | | PH2 | 0.996 | 0.054 |
| | | PH3 | 0.999** | 0.009 |
| | | M | 0.999* | 0.013 |
| | walking paths | PH4 | 0.999* | 0.027 |
| | | PH5 | 0.919 | 0.231 |
| | | M | 0.962 | 0.175 |
| | Children's playgrounds | PH6 | 0.999* | 0.029 |
| | | PH7 | 0.974 | 0.146 |
| | | PH8 | 0.997* | 0.049 |
| | | M | 0.999* | 0.028 |
| | Teens and youth play | PH9 | 0.991 | 0.085 |
| | | PH10 | 0.997* | 0.049 |
| | | M | 0.997* | 0.049 |
| | Sports and physical activities | PH11 | 0.954 | 0.195 |
| | | PH12 | 0.949 | 0.205 |
| | | M | 0.952 | 0.199 |
| | Suitable supporting facilities | PH13 | -0.912 | 0.269 |
| | | PH14 | 0.988 | 0.099 |
| | | PH15 | 0.999* | 0.030 |
| | | PH16 | 0.999* | 0.024 |
| | | PH17 | 0.999* | 0.024 |
| Other related settings | M | 0.993 | 0.077 | |
| | PH18 | 0.997* | 0.049 | |
| | PH19 | 0.997* | 0.048 | |
| | PH20 | 0.136 | 0.913 | |
| | PH21 | 0.733 | 0.438 | |
| M | PH22 | 0.999* | 0.033 | |
| | M | 0.995 | 0.085 | |
| | M | 0.998* | 0.045 | |
| | QA1 | 0.999* | 0.030 | |
| | QA2 | 0.968 | 0.160 | |
| Quality of the atmosphere | QA3 | 0.999* | 0.029 | |
| | QA4 | 0.999* | 0.021 | |
| | QA5 | 0.947 | 0.208 | |
| | QA6 | 0.892 | 0.299 | |
| | QA7 | 0.919 | 0.257 | |
| | QA8 | 0.999* | 0.017 | |
| | M | 0.996 | 0.054 | |
| | VQ1 | 0.999* | 0.021 | |
| 3D visual quality | VQ2 | 0.998* | 0.042 | |
| | VQ3 | -0.466 | 0.692 | |
| | VQ4 | 0.581 | 0.606 | |
| | VQ5 | 0.838 | 0.367 | |
| | VQ6 | 0.986 | 0.106 | |
| | VQ7 | 0.796 | 0.414 | |
| | M | 0.967 | 0.138 | |
| Meanings and values | MC1 | 0.937 | 0.227 | |
| | MC2 | -0.603 | 0.588 | |
| | MC3 | 0.196 | 0.875 | |
| | MC4 | 0.766 | 0.445 | |
| | M | 0.887 | 0.305 | |
| QPS | | | 0.999* | 0.035 |

** . Correlation is significant at the 0.01 level (2-tailed). * . Correlation is significant at the 0.05 level (2-tailed).

On the other hand, when discussing the details of the results of the indicators of the IDU tool, the final results of the IDU show the preference of both Al-Sabeen and Al-Thawra Parks (0.79, 0.71) over both Al-Tahrir and Al-Saleh Mosque Squares (0.58 and 0.54). The park's advantage has been

demonstrated in all indicators except the intensity of temporal use, which shows the advantage of Al-Tahrir Square. That does not mean its quality is higher, but because it is in a residential area, people continue to be in and through them as necessary activities. That confirms our argument that all indicators are an integral part. The results show that the intensity of spatial use is high in Al-Sabeen Park but low in the rest of the spaces. Although the rest of the indicators of Al-Thawra Park show positive results, the intensity of spatial use is poor. This might be due to the poor conditions of some areas in the park, as they need maintenance. In addition, the back area is not used in Al-Saleh Mosque Square, and the large green areas have not included seating places.

The intensity of social use is high in the parks and low in the squares. This is consistent with what was indicated by another study that examined the characteristics of visiting public spaces in Sana'a city. Yemenis go to parks as families and groups [95]. Although Al-Tahrir Square is Yemen's most culturally important public space, the results show a low intensity of social use, which is evidence of its poor state.

The intensity of gender diversity and age diversity is higher in both parks than in both squares. The results not only indicate a gender balance in the parks but also show that the rate of women is more. Similarly, the intensity of staying in is higher in both parks than in the squares. The results also show that the time spent by both the parks visitors is longer than the time spent by squares visitors. Although both parks do not have the necessary activities, the intensity of activities is higher in them than in the squares. The results also show that the necessary activities in Al-Tahrir Square are high, while social and optional activities are declining. The rate of social activities in both parks is the highest. The lack of optional and social activities is likely in Al-Tahrir Square due to its low quality. This is in line with what was stated by Abasi, Alalouch et al. (2016), their findings reveal that the decline in the quality of open spaces may lead to reduced social and optional activities [96].

From the above discussion, it can be concluded that one of the variables mentioned in the tool cannot be used without the rest of the variables. Using one variable may give unrealistic results about space conditions. As we indicated above, Al-Tahrir Square achieved the highest score in the intensity of temporal use and the lowest score in the rest of the indicators. Therefore, the seven variables mentioned in the tool must be used for the results to be effective and to reflect the diversity and intensity of space use. Subsequently, we state that the intensity of use may mean the continuity of the intensity and diversity of use and users in the temporal and spatial dimensions.

Time and space are inseparable and integrated factors in the built environment, and no way they can be separated when we want to understand people's behavior in space. Therefore, the most important advantage of our work is to add a spatial dimension to the methodology of the intensity of use in public places. Besides, we have used the time dimension extensively and in all indicators. Measuring the quality of public spaces by a methodology of intensity and diversity of use is prone to human error, especially when the space is crowded with people. Still, we were keen to obtain accurate results and sought to mitigate the possibility of the impact of mistakes by working for long periods and at different times. This methodology is still operational and takes a lot of time and effort, so we strongly recommend using new techniques to measure the intensity and diversity of use. This methodology can be implemented computationally by installing sensors in the spaces whose qualities are to be measured. This will undoubtedly facilitate the evaluation process and increase the efficiency of the results.

5. Conclusion

This study proposes to add a spatial dimension to the Mehta methodology when measuring the intensity and diversity of use in public spaces. It also addresses the time dimension more broadly. Through proposed mathematical equations, seven indicators were measured: the intensity of temporal use ITU, the intensity of spatial use ISU, the intensity of social use (ISCU), the intensity of age diversity IAD, the intensity of gender diversity IGD, the intensity of stay (IS), the intensity of activities (IA). On the other hand, the study surveyed the opinions of specialists to assess the quality of the public space from four aspects, i.e. the quality of the physical settings to facilitate the activities, the quality of the atmosphere, the visual quality, and the meanings and cultural values. The relationship between the IDU tool and the quality index of specific spaces was measured. The results showed a strong relationship between the use index and the quality of public spaces index. The results also showed that the IDU index is related to a set of spatial settings, namely the availability of the efficiency and adequacy of seating areas, footpaths, play facilities, and facilities supportive of various activities, separating pedestrian traffic from vehicle movement, space free of intruders and disturbing behaviors, and various natural and man-made elements in space. This tool was applied to four public spaces in Sana'a city: Al-Tahrir Square, Al-Saleh Mosque Square, Al-Sabeen Park, and Al-Thawra Park. They were chosen among the most important public spaces in Sana'a city because of their embrace of the daily activities of the city's

residents. The tool can also be applied in other types of urban open spaces, in which people practice their various daily activities.

The study recommends using advanced techniques to implement this methodology by installing sensors in parts of space. Sensors monitor people's behavior in space not for a quarter of an hour at each period of the day but during the hours of the day. Sensors can also accurately track the movement of people and count them as the number of people in space increases. Applying this tool using advanced computer technologies may open up advanced and new horizons in monitoring the relationships between people and their environment.

The study developed a tool for measuring the IDU in the public space besides developing another measuring tool which consists of the factors and items that measure the quality of public space, which went through a series of procedures for measuring the validity and reliability and concluded with 41 items which were classified into four aspects that measure the quality of the public space. Stakeholders can use the components of this tool for evaluating and developing existing open urban environments, and they may use this tool as a guide when they design new public spaces.

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