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Al-Qadisiyah Journal for Engineering Sciences

Journal homepage: https://qjes.qu.edu.iq

Research Paper

Active workplace: Architectural interventions for reducing sedentary behavior and promoting stair use

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ARTICLE INFO

Article history:
Received 17 March 2025
Received in revised form 11 May 2025
Accepted 07 November 2025

keyword:
Active design
Health promotion
Spatial configuration
Space syntax
Workplace

ABSTRACT

The task of creating active buildings largely depends on the integration of active design strategies into the building's circulation system especially its stairs and elevators—and its program. Despite the implementation of active design guidelines for promoting stair use, there is a lack of objective measures to assess their effectiveness. This study provides an empirical analysis of active design strategies utilizing self-reported questionnaires and spatial analysis using DepthmapX software in seven office buildings in Erbil, Iraq ($N = 240$ employees). The findings indicate a minimal inclination towards using stairs ($M = 1.24$), and a higher inclination toward using the elevator (M=1.46). Although participants reported high satisfaction with stair design ($M > 3.5$), the findings revealed no significant association between stair design and frequency of use ($p > 0.05$). This study found that the outcome is attributable to the spatial configuration, namely the absence of social and recreational facilities throughout various floors of the building. The result of the self-reported questionnaire is supported by objective spatial analysis, which indicates positive significant correlation between spatial configuration in terms of connectivity, accessibility, visibility, and stair use. Based on the findings, it is advised that efforts to encourage stair use should go beyond just concentrating on the architecture of the staircase. Enhancing spatial configuration by improving connectivity, accessibility, and visibility, as well as incorporating leisure areas and the strategic allocation of the building program across various levels appears, to be a beneficial strategy in promoting stair use and reducing Sedentary behavior (SB).

1. Introduction

Architecture, interior design, and health may appear unrelated at first inspection, but their effective integration can have a significant impact on public health and well-being. When architects and designers collaborate closely with public health professionals, they can design environments that actively promote health and well-being [1]. The combination of architectural principles and public health interventions can lead to the creation of more health-conscious and environmentally friendly environments. This, in turn, contributes to the improvement of public health outcomes and the enhancement of community quality of life. In the 21st century, SB has emerged as a significant health concern [2]. This issue is characterized by protracted amounts of sitting or inactivity,4 which involves little or no physical movement [3]. In modern society, SB has become increasingly prevalent due primarily to technological advancements, changes in work patterns, and lifestyle decisions resulting in severe health outcomes, including non-communicable diseases and premature mortality [4–8]. The built environment is characterized by both the objective and subjective qualities of the physical environment where individuals spend their t,ime and therefore, one of the many factors that contribute to increased SB [1,9]. The workplace is a setting that is associated with high levels of SB, with evidence that office-based employees can spend up to 82% of their working day sitting [10–13], which is equivalent to up to 438 minutes per day [10]. Several countries, including the United States, the United Kingdom, Australia, Canada, and the Netherlands, have recently recognized the dangerous increase in SB and its associated health risks including all-cause, cardiovascular disease and cancer mortality, and the incidence of cardiovascular disease, cancer and type 2 diabetes [14], and as a result, they have adopted the active design concept. It's a multidisciplinary health-oriented design approach that aims to design and change living and working spaces to make it easier for people to be active every day [15–21]. The advancement of technology, urbanization, and changes in work conditions have all contributed to more inactive lifestyles, pushing architects and urban planners to include active design concepts to combat these tendencies. The first concept of active design was developed in 2010 in New York City and seeks the intentional incorporation of features and elements that encourage physical activity (PA) and promote a healthier lifestyle through design principles, specifically in the workplace context where people spend the majority of their waking hours. The concept of active design aims to counteract SB and its associated health risks by creating environments that make it easier and more enjoyable for people to engage in physical activities as part of their daily routines. The active design guideline contains evidence-based and best-practice suggestions for increasing PA in the design and construction at both urban and building scales. At the building scale, Active Dsign focuses on integrating architectural and spatial strategies that encourage movement and PA within built environments. A particular aspect of active building design focuses on staircases and their capacity to enhance PA levels. Staircases, when designed strategically and aesthetically, can encourage people to choose stairs over elevators or escalators for short trips, thereby promoting regular PA as part of their daily routines.

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https://doi.org/10.30772/qjes.2025.158353.1524

Nomenclature

PA	Physical Activity	*SB*	Sedentary Behaviour
BMI	Body Mass Index	*Z*	Z-score
N	Population size	*P*	Proportion of the population
e	Margin of error	*SD*	Standard Deviation

Previous studies have provided empirical evidence indicating that individuals have a greater propensity to utilize staircases when they are conveniently positioned and when the architectural layout emphasizes both safety and aesthetic considerations [22]. Jancey et al (2016) [23] suggest that locating the stairs along the main path of circulation and making them visible to the user will increase stair use. Also, centrally located staircases are more accessible and used compared to hidden staircases. PA is facilitated by accessibility in the workplace [24], which addresses the distance between the building's staircases and outdoor and indoor spaces [22]. Theoretically, environmental features of the built environment, such as accessibility and aesthetics, are assumed to have a large effect on behavioral choices [25], but empirical evidence is limited. In certain structures, large atria connecting many stories can be used to provide accessible and colorful staircases [26]. In addition, several studies suggest that point-of-decision prompts such as motivational signage can increase stair use [27–29]. Decorating stairwell walls with artwork and changing them every month can help enliven the stairwells and promote their use [30]. Visual-attractive strategies that increase stair use include high-quality designed staircases in terms of materials and finishes, as well as providing a visual connection from the staircase to an attractive outside view [31]. For comfort and safety, appropriate stair tread width and riser height compatible with human anthropometric dimensions are more likely to be used [32].

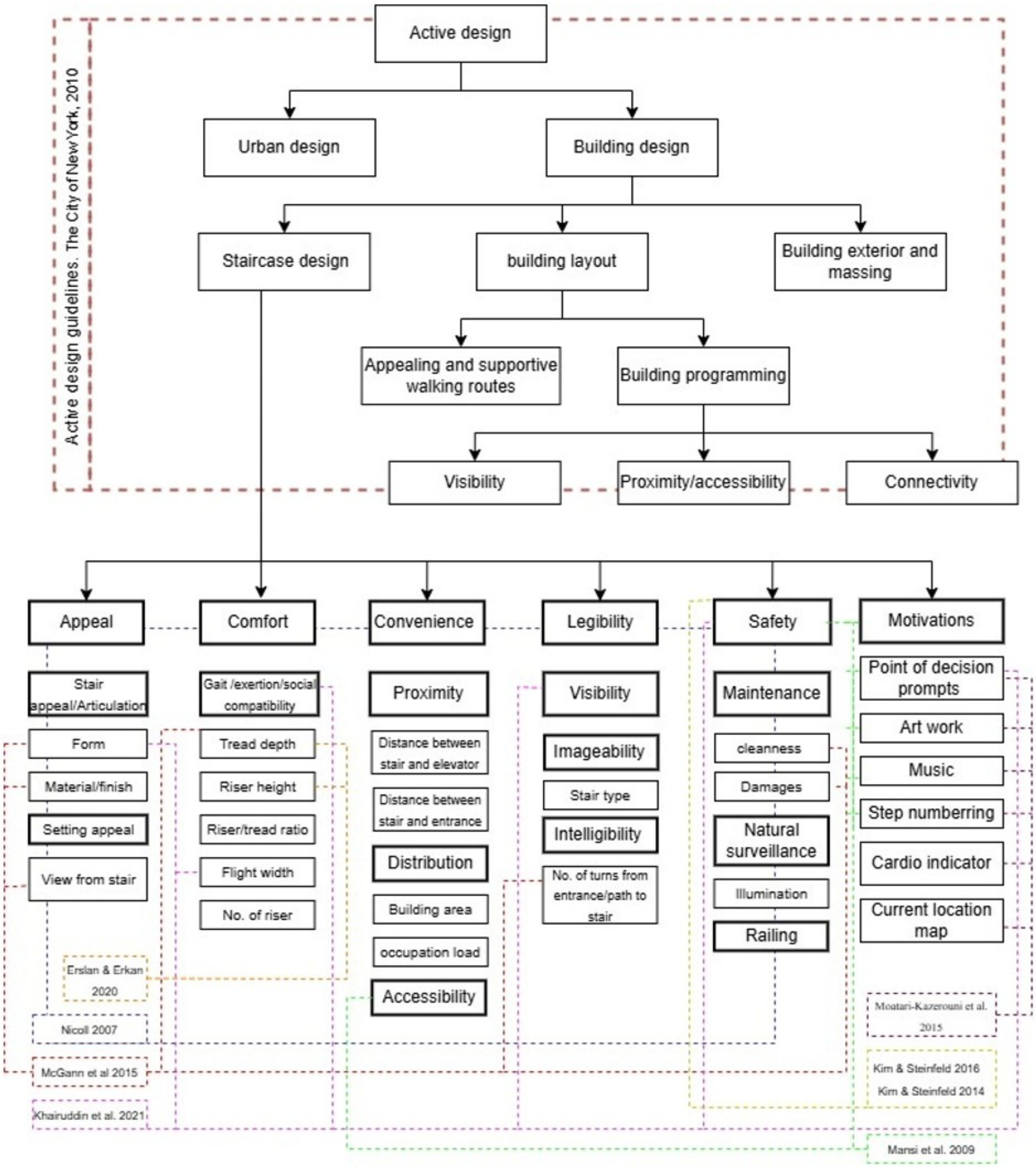


Figure 1. Analytical summary of factors affecting stair use [1].

Stair maintenance, repair, and the provision of appropriate natural and artificial lighting improve stair safety and encourage more stair use. Figure 1 provides an analytical summary of factors affecting stair use based on previous literature. In addition to staircase design, active design also considers building programming and layout as a strategy for enhancing stair use. A recent study on workplace circulation design and PA analysis revealed statistically significant differences in workers' PA behaviors, including mean PA intensity, sedentariness (in minutes), step counts, and self-reported stair usage, across three case studies characterized by distinct architectural characteristics in their circulation spaces [33]. Also, studies revealed that the spatial layout of the workplace significantly affects the frequency of stair use and PA. The spatial layout of the office can be used to assess the workspace's accessibility, connectivity, visibility, and proximity to shared areas and coworkers [34, 35]. Moreover, the spatial configuration of a building—encompassing factors such as connectivity, visibility, and accessibility—significantly influences stair use. Research indicates that when staircases are centrally located and well-integrated into frequently used pathways, individuals are more inclined to choose stairs over elevators. For instance, a study analyzing ten academic buildings found that features like the distribution of stairs, their visibility (measured by the area of stair isovist), and their proximity to main entrances collectively accounted for 64% of stair use in these buildings [22]. Although active design guidelines provide staircase design strategies to encourage PA, few studies have objectively evaluated their effectiveness in real-world workplace settings. Furthermore, although spatial layout—especially interpreted using Space Syntax—has been extensively investigated in various research related to urban analysis [36, 37], road analysis [38, 39], buildings function [40], locations [41], mobility and navigation in buildings [42, 43], its direct impact on stair usage behavior is yet unknown. No known study has integrated both active design evaluation and space syntax analysis to isolate the key architectural factors that influence stair usage.

(a) Building 1 (Z-shape) (b) Building 2 (Y-shape) (c) Building-3 (x-shape)

(d) Building 4 (I shape) (e) Building 5 (O-shape) (f) Building 6 (I-shape) (g) Building 7 (L-shape)

Figure 2. Architectural plan of seven office buildings.

To address these gaps, this study sets out to achieve the following objectives:

- To evaluate the effectiveness of active design guideline implementation on staircase use in workplace settings.
- To examine the influence of building spatial configuration on stairs use using objective spatial analysis techniques (e.g., space syntax theory, depthmapX software).
- To compare the relative contributions of staircase design quality and spatial configuration in predicting stair use behavior.
- To develop evidence-based recommendations that integrate active design principles with spatial configuration strategies for promoting stair use in architectural design.

2. Methods

2.1 Settings and participants

Since office workers are subjected to SB and its negative consequences, this study was designed to be conducted in governmental office buildings in Erbil, Iraq. Because of the massive number of government office buildings, a set of criteria that fulfill the aim of the study has been designed to restrict the number of government office buildings to a reasonable extent. According to the literature, office-based employees are the main concern of this type of study. The seven criteria for selecting cases include criteria (1): Building function should be either Ministries or well-known government departments; criteria (2): The building should be in Erbil city center; criteria (3): The building should be constructed or (reconstructed) after the year 2000; criteria (4): The building should not be less than three floors; criteria (5): The number of employees should not be less than 50 employee in the building; criteria (6): The type of work in the building should be office based; criteria (7): The building should contain stairs and an elevator to be included in the study. Nine buildings were selected to match the above-mentioned criteria, however, two of them didn't provide consent due to some security and privacy issues related to the workplace. Therefore, this study was conducted in seven government office buildings with different layouts (Figure 2), between May 2022 and July 2022. After obtaining written consent from the authorities responsible, all employees from selected workplaces were invited to participate in the survey (N=760), with complete freedom to participate in the survey:

Building-1: General Directorate of Electricity
Building-2: Ministry of Justice
Building-3: Judicial Council
Building-4: General Directorate of the Taxation & State Real Estates
Building-5: Ministry of Endowments and Religious Affairs
Building-6: Urban Planning Directorate
Building-7: General Directorate of Real Estate Registration

The selection of sample size was based on the total number of office-based employees in all cases which was 760 employees. Then, the formula (equation 1) to estimate the actual number of questionnaires required which was found to be 256 employees, Eq. 1.

$$n = \frac{N \times Z^2 \times p \times (1-p)}{(N-1)e^2 + Z^2 \times p \times (1-p)} \quad (1)$$

Where n = required sample size. N = population size. Z = Z-score (based on confidence level, e.g., 1.96 for 95%). p = estimated proportion of the population (use 0.5 if unknown, for maximum variability). e = margin of error (e.g., 0.05 for ±5%). A total of 290 questionnaires were distributed randomly to ensure representation of the general population, of which 240 were completed and returned, representing a response rate of approximately 83% of the distributed surveys.

2.2 Pilot study

A pilot study was conducted over one full working day in each building to observe employees' behavior regarding stair and elevator use. The findings from this pilot study were later utilized in designing the survey to effectively fulfill the study's objectives. During the pilot study, random employees were selected and asked about the number of stairs used per working day. The minimum number of stairs recorded was zero time (no use) the maximum was ten times. This helped us to design the self-reported questionnaire about stair use frequency in five Likert scales.

2.3 Data collection

2.3.1 Survey

In this research, a self-reported questionnaire was designed comprising four sections Appendix -A.

Table 1. Active design strategies for promoting stair use [15].

Strategies		Strong evidence	Emerging evidence	Best practice
Convenience	Designating stairs for everyday use		• Provide one or all stairs in a building for everyday use, whether in the form of a grand staircase or fire stairs that also serve as a principal means of travel. • Focus on stairs rather than elevators as the principal means of vertical travel for those who are able to climb the stairs. • In high-rise buildings, provide an integrated vertical circulation system that incorporates stair use for travel between adjacent floors, so that elevators are used primarily for vertical travel of four floors or more. • Integrate the stairs with the principal areas of orientation and travel within the building	• Make the stairs accessible to the public areas of the building and, where possible, eliminate locks between staircases and floor areas.
	Stair location and visibility		• Locate stairs near the building's entrance. • Locate a stair targeted for everyday use near the elevator. • Locate an appealing, visible stair directly on the building's principal paths of travel.	• Design stairs to be more visible. Use one or more of the following: • Fire-rated glass enclosures instead of traditional opaque enclosures. • Open stairs between two or more floors with either the same or associated tenancies.
Comfort	Stair dim.		• Make stairs wide enough to accommodate travel in groups and in two directions. • Design stair risers and treads that are comfortable and safe.	
Appeal & safety	Appealing stair environment		• Use articulated and unique stair compositions. • Design stair environments that appeal to the senses.	• Provide visually appealing interior finishes. • Design safe stairs. • Provide well-lit stair environments. • Design stairs to be easily maintained.
Motivation	Stair prompts	• Place signage at elevators and escalators to encourage stair use.	• Locate stairs where they will be most visible. • Design informational and motivational messages to be linguistically and culturally appropriate to the building's users.	
Building programming	Common/shared facilities			• Locate building functions to encourage brief bouts of walking or travel to commonly used amenities. • Consider locating the principal building lobby functions on the second floor accessible by a prominent grand stair or ramp, as well as by a less prominent elevator, to encourage walking. • Consider locating shared functions on alternative floors, adjacent to staircases or ramps.

The first section related to demographic questions age, gender, height, and weight of each participant to calculate Body Mass Index (BMI). Second section related to stair and elevator use frequency, participants were asked to report how often they used the stairs or elevator within a working day, using a structured scale ranging from 0–2 times, 2-4 times, 4-6 times, 6-8 times, and 8–10 times per day. This approach provided a quantifiable measure of stair usage, allowing for a detailed analysis of behavioral patterns. The third section was related to the measure of stair design based on Active design guidelines. The Guidelines translate health research into design strategies that promote a more liveable city in which residents can easily engage in PA and make healthier choices daily [15]. The Guideline suggests several strategies for promoting stair use based on evidence as illustrated in (Table 1) extracted from active design guidelines-building design. Strong evidence indicates design strategies supported by a pattern of evidence from at least two longitudinal or five cross-sectional studies. The strength of the research allows us to discard alternative hypotheses and to conclude that there is a direct relationship between the suggested environmental intervention and the behavioral outcome. Emerging evidence indicates design strategies supported by an emerging pattern of research. Existing studies give reason to believe that the suggested environmental intervention will likely lead to increased PA, but the research is not yet definitive. Best practice indicates design strategies without a formal evidence base. However, theory, common understandings of behavior, and experience from existing practice indicate that these measures will likely increase PA. In this section, participants were asked about their perception of staircase design in their workplaces. Five design parameters were measured as mentioned previously based on active design guidelines regarding stair use excluding the motivational sign strategy since none of the workplaces use motivational signs for promoting stair use:

Convenience. User convenience towards the stairs is measured by accessibility. Accessibility of the stairs includes whether the staircase is accessible to all users without any obstacles or effort to reach it [22, 26]. Three possible levels of accessibility include limited accessibility, which is no or limited accessibility between stairs and adjacent spaces or exterior; selective accessibility, which requires a key or pass card for entry; and open accessibility, which is unrestricted access [21].

Visual appeal. Studies show that the visual appeal of stairs affects the frequency of stair use. The appeal is divided into two parts: stair appeal, including form, material, and finishing of the stairs [22, 24, 26, 44]. Staircase visual appeal can be divided into three groups: basic stairs, which have few details and finishes; enhanced stairs, which have improved finishes or a different shape; or articulated stairs, which have details, finishes, and parts that make them stand out. While setting appeal includes the view from the stairs, particularly to the outside [22, 24].

Comfort. Comfort is another important factor in designing stairs. The more comfortable, the more used by people. This includes the geometry of the stairs, e.g., tread depth, riser height, riser/tread ratio, flight width, and the number of steps [22, 25, 32, 44].

Safety. Safety is the most prominent factor that affects stair use. Besides the geometry and comfort dimension of stairs, other aspects of staircase design affect the sense of safety, such as the provision of railing and sufficient illumination, including artificial and natural lighting. Also, periodical maintenance prevents damage and serious accidents [22, 24, 26, 30, 44–46].

Building programming. Building programming provides an efficient strategy for incorporating PA into daily life by providing incidental movement between spaces. One of the most prominent strategies in building programming is the provision of shared facilities, e.g., (WC, cafeteria, restaurant, library, meeting room, central gathering area, prayer room, etc.) in the building to be accessible by all [15]. In addition to provision, the placement of these facilities in the building and distribution of them among different floors and beside the staircases play a critical role in increasing incidental walking and stair use. In the workplace, the building's programming should connect all floors so that the employee constantly travels between floors [47]. In addition, the participants were asked about the primary reason they avoid using the staircase in an open-ended question to provide a comprehensive understanding of stair use behavior.

2.3.2 Spatial analysis

The spatial configuration of a building—defined by connectivity, visibility, and accessibility—directly influences stair use by affecting how people perceive and interact with staircases in their daily movement patterns. Architectural design plays a crucial role in encouraging or discouraging stair use based on how intuitively and conveniently stairs are positioned relative to key destinations.

Connectivity and Stair Use. Connectivity refers to how well a staircase is integrated within a building's circulation network. When stairs are highly connected to frequently used areas—such as entrances, workstations, and communal spaces—users are more likely to choose them over elevators. A building with centralized, well-linked staircases naturally encourages stair use, whereas poorly connected stairs, requiring detours, reduce the likelihood of use.

Visibility and Stair Use. Visibility determines whether stairs are easily noticeable upon entry or hidden behind walls and doors. Open staircases with glass enclosures or centrally positioned designs attract more users, while enclosed staircases that are out of sight are often ignored in favor of elevators. Research suggests that when stairs are visible from main pathways, their usage increases significantly.

Accessibility and Stair Use. Accessibility refers to how easy it is to reach the stairs compared to elevators. When stairs are placed closer to main entrances or require fewer barriers (e.g., no doors, direct paths), they are used more frequently. In contrast, if elevators are the default option, such as being positioned directly in front of users upon entry, stair use declines. Additionally, the design of stairs, such as wider steps, comfortable riser heights, and aesthetic appeal, contributes to ease of access and increased use. Buildings designed with highly connected, visible, and accessible staircases naturally promote active stair use. Spatial analysis techniques such as Space Syntax (Depthmap) can help architects evaluate stair placement by analyzing integration values, connectivity, and visual prominence. By strategically designing staircases, buildings can encourage PA and contribute to healthier indoor environments.

2.4 Statistical analysis

The data gathered from the questionnaire encompass several key elements: demographic information of participants (age, gender, BMI), the daily count of stairs used by each participant, their perceptions concerning stair design and quality, and the factors influencing their decision to refrain from using stairs. To achieve the aim of this study, the following statistical analyses were conducted; Reliability test to measure the consistency and stability of a measurement scale. Frequencies & descriptive analysis to measure frequency, percentages, mean values, and Standard Deviations SD of the data. Bivariate correlation to examine the correlation between quality of stair design and frequency of stair use. Also, a bivariate correlation was used to investigate the correlation between stair use and BMI of participants as well as a partial correlation to examine the relationship between building spatial configuration (connectivity, accessibility, and visibility) and stair use frequencies.

3. Results and discussions

3.1 Survey results

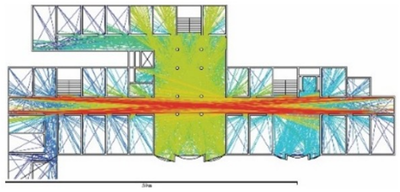
Before starting the data analysis, the consistency and dependency of the collected data were checked by conducting a reliability test. The result reveals a high consistency of data, which includes sixteen questions that were directed toward the participants according to Cronbach's Alpha (0.867), as shown in Table 2.

Table 2. Characteristics by gender, age, BMI, frequency of stair use, quality of stair design Active Design strategies, and reasons for not utilizing stairs.

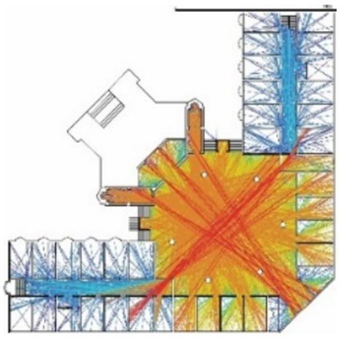
Cronbach's Alpha	N of Items
.867	18

Table 3. Reliability analysis for the self-reported questionnaire.

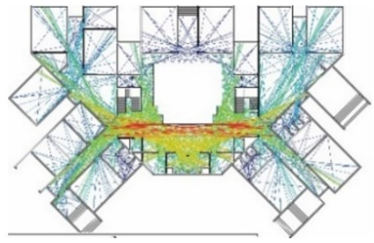
Item	N (%)	Mean (SD)
Gender		
Male	108 (45%)	
Female	132 (55%)	
Age		39.57 (9.50)
(19-29) year	21 (8.8)	
(30-39) year	118 (49.2%)	
(40-49) year	57 (23.6%)	
(50-59) year	34 (14.2)	
(60-69) year	10 (4.2%)	
BMI		26.23 (4.23)
Underweight (<18.5)	4 (1.7%)	
Normal (18.5-25)	71 (29.6%)	
Overweight (26-30)	125 (52.1%)	
Obese (>30)	40 (16.7%)	
Stair use		1.24 (0.74)
(0-2) times	214 (89.2%)	
(2-4) times	5 (2.1%)	
(4-6) times	13 (5.4%)	
(6-8) times	6 (2.4%)	
(8-10) times	2 (0.8%)	
Elevator use		1.45(0.74)
(0-2) times	163 (67.9%)	
(2-4) times	51 (21.3%)	
(4-6) times	21 (8.8%)	
(6-8) times	5 (2.1%)	
(8-10) times	0 (0.0%)	
Active design strategies		
Convenience		3.93 (0.69)
Comfort		3.79 (0.94)
Safety		3.63 (0.64)
Appeal		3.56 (0.67)
Building programming		1.73 (0.68)
Reasons for not utilizing stair		
Don't need it	189 (78.8%)	
Arthritis and	14 (5.8%)	
Makes me tired	15 (6.3%)	
Wearing high heels	12 (4.9%)	
Others	10 (4.2%)	



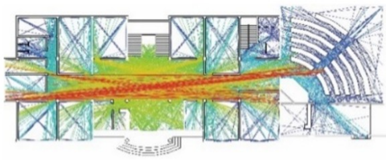
(a) Building 1 (Z-shape):472.73



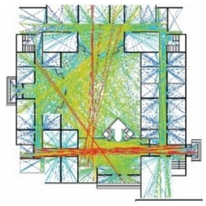
(b) Building 2 (Y-shape):374.21



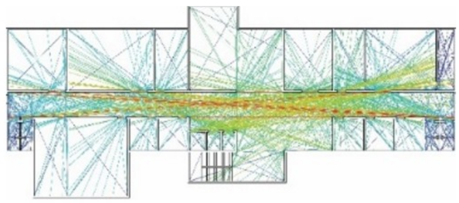
(c) Building-3 (x-shape):150.67



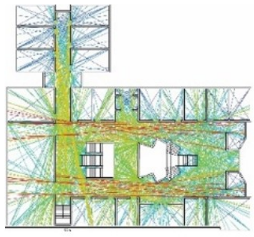
(d) Building 4 (I shape):335.03



(e) Building 5 (O-shape):229.84

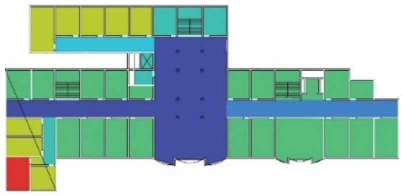


(f) Building 6 (I-shape):163.38



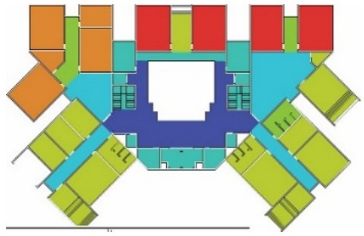
(g) Building 7 (L-shape):190.18

Figure 3. Axial connectivity map of the ground floor of seven office buildings.



(a) Building 1 (Z-shape):3.23

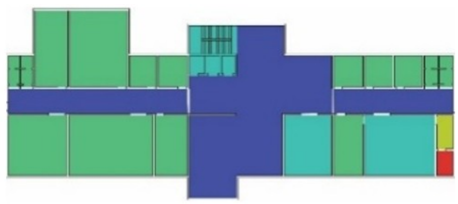
(b) Building 2 (Y-shape):3.04



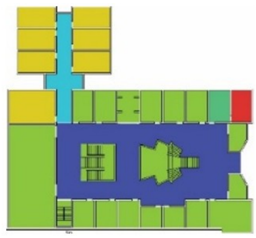
(c) Building-3 (x-shape):3.66

(d) Building 4 (I shape):2.66

(e) Building 5 (O-shape):3.39



(f) Building 6 (I-shape):2.67



(g) Building 7 (L-shape):2.41

Figure 4. Convex map (mean depth) of the ground floor of seven office buildings.

Descriptive analysis of the self-reported questionnaire data (Table 3) revealed that 55% of participants were female employees, while 45% were male. The average age of participants was 39 years.

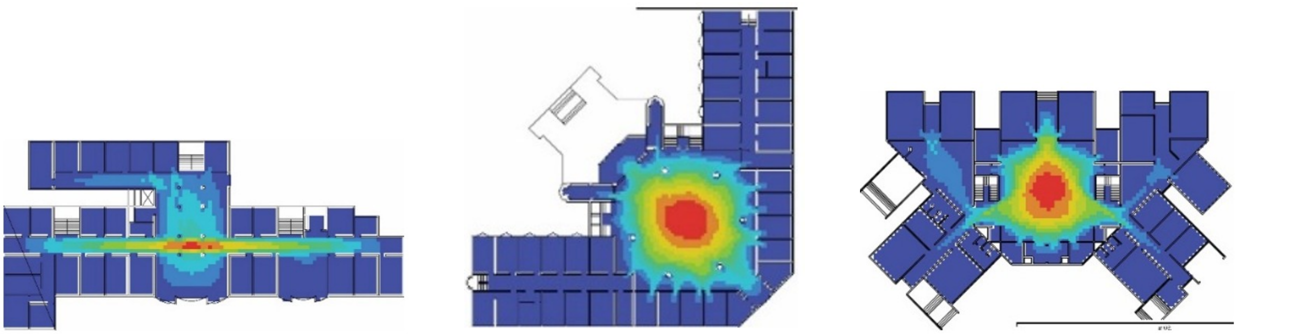
Table 4. The mean difference between stair use and elevator use.

	Mean (DS)	**95% Confidence Interval of the Difference**		t	df	**Sig. (2-tailed)**
		Lower	Upper			
Stair use-Elevator use	-.212 (1.039)	-.345	-.080	-3.168	239	.002

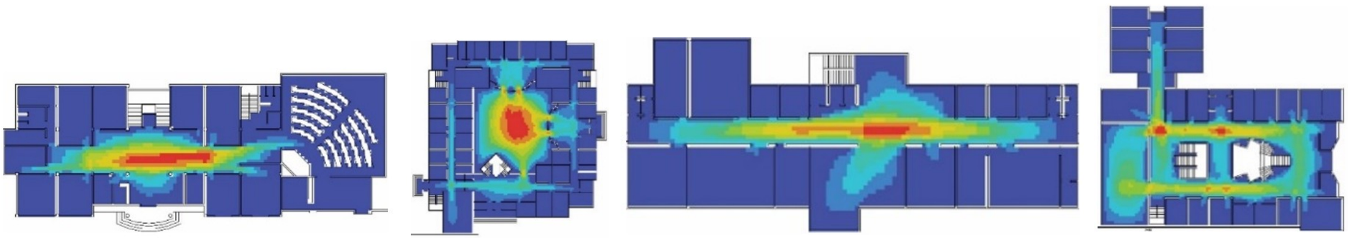
Table 5. Correlation analysis between stair use, stair design, and BMI.

Correlation analysis	**Stair use**		**95% Confidence Interval**	
Staircase design quality	Pearson Correlation	Sig. (2-tailed)	Lower	Upper
Convenience	0.009	0.895	-0.076	0.091
Safety	0.078	0.228	-0.014	0.170
Comfort	-0.005	0.943	-0.110	0.097
Appeal	0.080	0.218	-0.037	0.194
Building programing	-0.030	0.647	-0.122	0.063
Body mass index	-0.166	0.010*	-0.291	-0.031

Where (∗) is correlation is significant at the 0.05 level (2-tailed).



(a) Building 1 (Z-shape):4524 (b) Building 2 (Y-shape):9339.85 (c) Building-3 (x-shape):1417



(d) Building 4 (I shape):5523 (e) Building 5 (O-shape):7793 (f) Building 6 (I-shape):8841 (g) Building 7 (L-shape):11452

Figure 5. VGA (Through vision) analysis of the ground floor of seven office buildings, where a, b, and c are Radial building layouts, while d, e, f, and g are Linear building layouts.

In terms of age distribution, 49.2% were between 30-39 years old, 23.3% were aged 40-49 years, 14.2% were between 50-59 years, 8.8% were aged 19-29 years, and 4.6% were above 60 years. Regarding Body Mass Index (BMI), the majority of employees were overweight (52.1%), while 29.6% fell within the normal range. Additionally, 16.7% were classified as obese, and only 1.7% were underweight. The second section regarding the frequency of stair use shows a low demand for stair use with mean value of 1.24 (SD=0.736). 89.2% of the participants claim that either they don't use stairs, or they use it maximum of two times, one time when they start working day and one time when they leave. 5.4% use stairs between 4-6 times, 2.5% between 6-8 times, 2.4% 2-4 times, and only 0.8% use stairs between 8-10 times but not more than 10 times. On the other hand, the use of the elevator was significantly higher than stair use with a mean value of 1.45 (SD=0.741) referring to prevalent SB among the office workers as shown in (Table 4) with p-value = 0.002 (<0.05). However, despite the low rate of stair use, the participants show a positive attitude toward the staircase design (mean value > 3.5) except for building programming (M=1.73). The last section of the survey poses an open-ended inquiry about the reason for not using the staircase. 78.8% of the participants revealed that they don't use stairs because they don't need to. A group of participants stated that they are not using stairs due to their health situation, 6.3% stated that using stairs makes them feel tired for different reasons, including being overweight and obese, heart problems, asthma, short breath, and 5.8% due to joint pain (arthritis) and back pain (Prolapsed Disc). A part of the female participants accused their outfits and high-heeled shoes of not using the staircase and preferring the use of the elevator. However, the elevator use rate was as low as the stairs since most of the participants revealed that they didn't need to visit the upper floors. The collected data about participants' perception of staircase design and their frequency of stair use were examined to find a correlation between the dependent variable (frequency of staircase use) and the independent variable (quality of staircase design) (Table 5). The result of correlation analysis demonstrates no significant correlation between the two variables (p-value > 0.05), even though it shows a negative correlation in some variables (e.g., comfort -0.005 & motivations= -0.030). On the other hand, a significant negative correlation was found between frequency of stair use and BMI (p-value= .01).

3.2 Spatial analysis result

3.2.1 Connectivity

Axial connectivity. The connectivity value of an axial line is the number of axial lines directly connected to the line. This local property of an axial line is interesting because it describes the degree of choice present on the line: The greater the connectivity of an axial line, the greater the choice of movement from the line [48]. The highest axial map connectivity was identified in building-1 with a Z-shape radial layout typology, with an average connectivity of 472.73 in a four-floor building, while the lowest connectivity value was identified in building-3, radial layout with an average of 150.67 in a three-floor building. Moreover, the second highest connectivity degree was followed by building-2, radial layout, with an axial map connectivity result of 374.21, followed by the linear layout, which belongs to building-4 with an I-shape and a connectivity value of 335.03. Moreover, the axial connectivity map of all seven buildings' ground floors is illustrated in Fig. 3 with their connectivity values. The red line refers to the highest connectivity, while the blue line refers to the lowest connectivity value.

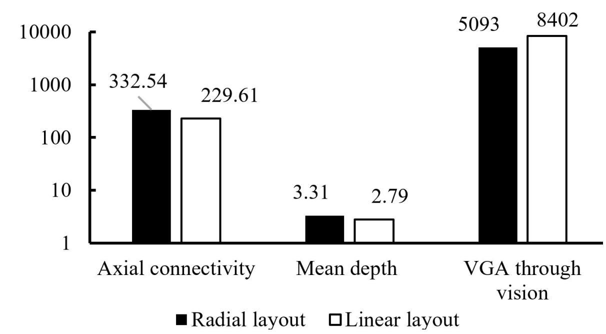


Figure 6. The quality of Spatial configuration in linear and radial layout.

Table 6. Correlation between spatial configuration and stair use frequency.

Spatial configuration parameters	Partial Correlation	Significance (2-tailed)	95% Confidence Interval	
Connectivity	0.710	0.000*	0.623	0.871
Accessibility	0.611	0.000*	0.516	0.698
Visibility	0.697	0.000*	0.605	0.778

Where ($*$) is correlation significant at the 0.01 level (2-tailed).

3.2.2 Accessibility

A convex mean depth. Convex map means depth characterized by the most segregated areas in the office buildings to measure the accessibility of spaces. The convex spaces can be transformed into a diagram in which convex spaces are represented by points and relationships between them by lines joining points. The convex map can be defined as a minimal number of convex polygons that are connected, which is used to consider the configurational relationship among spaces. In this study, the mean depth of the convex map was used to measure the accessibility of the building spaces. The highest degree of depth considers the high distance between spaces and less accessibility, while the less depth value refers to the shortest distance and more accessibility between spaces. The radial layout Building-3, with an X-shape was interpreted as less accessible by recording the highest mean depth value of 3.66 compared with other layouts. The Building-7 linear layout scores the lowest value of mean depth of 2.41, indicating that it's the most accessible layout compared with others. The convex depth map of all seven buildings' ground floors are illustrated in Fig. 4 with their mean depth values. The red spaces refer to the highest depth value, while the blue color refers to the lowest depth value.

3.2.3 Visibility

Visibility graph analysis. A "Thorough vision" is described as the longest possible continuous view. "Through vision" spatial metric was described first in 2007 by Turner (2007) [49] as a way to pinpoint the locations that are crossed over more often and can thus be considered important for movement. "Through Vision" can be defined as the number of lines of visibility that pass through a location. In more formal terms, each cell in the grid is the number of times it is crossed by lines drawn between the centroids of all other inter-visible cells. This metric can be used to pinpoint locations most likely to be traveled, given that they are "in the way" to get from one position to another. It is thus expected to relate to movement, especially in spaces that have long and straight walkable lines. "Through vision" builds a bridge between the line-based topological analyses of space syntax and visually directed agents. The highest value of "through vision, or in other words, the longest possible continuous view, is recorded in a linear layout building with a value of 11452, which belongs to building-7 while the lowest possible continuous view is recorded in a radial layout with a value of 1417, which belongs to Building-3. The VGA map of all seven buildings' ground floor is illustrated in Fig. 5 with their "Through vision" values. The red spaces refer to the highest through vision value, while the blue color refers to the lowest through vision value. The comparison between case studies identified that the average connectivity value in three radial layout buildings is 332.54, while in four linear layout buildings, it is 229.61. Similarly, the average integration value is 3.31 in radial layouts and 2.79 in linear layouts. Additionally, the average through-vision value is 5,093 in radial layouts and 8,402 in linear layouts, as illustrated in Fig. 6 indicating that linear layout has better spatial configuration in terms of both accessibility and visibility. To compare the results from the self-reported questionnaire and the objective measures of spatial configuration in terms of stair use, a partial correlation was conducted between self-reported stair use and parameters of spatial configuration. The partial correlation in Table 6 shows a positive and significant relation between the two items. The correlation table presents the relationship between stair use frequency and three spatial quality factors: connectivity, visibility, and integration. The correlation coefficients (R-values) indicate the strength and direction of these relationships. The results show that connectivity and stair use frequency have a strong positive correlation ($r = 0.710$, $p = 0.000$), meaning that as connectivity increases, stair use frequency also tends to increase. Similarly, visibility and stair use frequency exhibit a strong positive correlation ($r = 0.697$, $p = 0.000$), suggesting that spaces with higher visibility encourage more stair use. Lastly, integration and stair use frequency show a moderate to strong positive correlation ($r = 0.611$, $p = 0.000$), indicating that higher spatial integration is associated with increased stair usage. Since all p-values are 0.000, these relationships are statistically significant, meaning they are unlikely to be due to chance. The confidence intervals further confirm these findings, as the lower and upper bounds remain within a strong positive range for all variables. These results suggest that better spatial quality—measured through connectivity, visibility, and integration—encourages more frequent stair use in the studied environment.

4. Conclusions

Improving public health via the use of design and architectural concepts is the main goal of this research. Despite what would at first seem like a strange claim, actual data indicate that architects—rather than doctors—can have a greater influence on public health, albeit in the preventative rather than the curative domain. SB is a major cause of chronic and non-communicable illnesses in the twenty-first century. It is a well-known fact that people's behavior is significantly impacted by the physical environment's architecture, as Winston Churchill once said, "We shape our buildings, and thereafter they shape us". As such, architects have a significant influence on how building occupants behave. This study focuses on the staircase, a particular architectural element capable of integrating incidental PA into daily rituals. To design staircases that encourage PA, one must create environments that encourage people to take the stairs rather than elevators or escalators. Several organizations, including the Center for Active Design in New York City, have developed active design guidelines for increasing PA. These guidelines include urban and building-scale design elements intended to promote regular PA in everyday life. Among these elements, staircases stand out as a central feature of the building. The guidelines provide architects with several recommendations to consider when designing and positioning staircases within buildings, as well as the spatial configuration of the building. In conclusion, the results of this investigation indicate that the implementation of active design guidelines for staircase design does not have a direct impact on the behavior of stair users in workplace environments. The design strategies were not significantly correlated with actual stair use, even though the design was generally deemed satisfactory. This outcome contrasts with previous studies that have reported a positive association between active design strategies and increased PA, particularly stair use, which is listed in Fig. 1. Nevertheless, the spatial configuration of the structure was identified as a substantial factor that influenced the use of the stairs. Higher stair use was observed in buildings with superior spatial configurations in terms of connectivity, accessibility, and visibility, as determined by objective spatial analysis tools such as DepthmapX. These findings reinforce the self-reported data from the questionnaire, in which 78.8% of participants indicated that they do not use the stairs because they "don't need to," pointing to the poor spatial distribution of spaces across floors. These findings imply that although the quality of staircase design by itself might not be enough to inspire stair use, maximizing building spatial arrangement and configuration is rather important in supporting this behavior. These observations lead the study to develop evidence-based suggestions combining active design concepts with spatial arrangement techniques to efficiently promote stair usage in architectural design, therefore supporting a more active and healthier built environment.

Appendix-A

Dear Participant, thank you for spending 15 minutes of your time to fill out this survey. This survey aims to know the effect of workplace design on employees' physical activity and identify the factors that influence their physical and health activities in general.

Q/Please tick the answer that is correct for you, where 1:Strongly Disagree; 2: Disagree; 3: Neutral; 4: Agree; 5: Strongly Agree.

	Items	1	2	3	4	5
Convenience	The staircase(s) are visible and accessible from the entrance.					
	I can access staircase from my workstation easily without obstacles..					
Safety	The staircase(s) existing in my workplace are safe to use.					
	There are no/minimum damages in the staircase in my workplace.					
	The staircase(s) in my workplace maintained regularly.					
	The staircase(s) in my workplace is well lighted and safe to use.					
Comfort	The staircase(s) existing in my workplace are with comfort height.					
	The staircase(s) existing in my workplace are with comfort width.					
	The staircase(s) wide enough to allow group climbing while conversing and preventing crash.					
Appeal	The design of staircase(s) in my workplace is attractive.					
	The finishes and environment around the staircase are attractive and give unique appeal sense.					
	The staircase has an attractive view to outside.					
	The staircase has an attractive view to internal court or atrium.					
Building programming	The shared facilities (cafeteria, restaurant, meeting room - resting places, etc.) are available for use in my workplace.					
	The shared facilities (cafeteria, restaurant, meeting room - resting places, etc.) are accessible and distributed among different floors.					

Q/What is the most obvious reason behind not using a staircase?
A/ (...)

Q/Demographic questions

Age:	$(year)$	Height:	(cm)				
Weight:	(Kg)	Gender:	Male:	☐	Female:	☐	

Q/How many times do you use the staircase in one normal working day?

	(0-2) times	(2-4) times	(4-6) times	(6-8) times	(8-10) times
Staircase					
Elevator					

Authors' contribution

All authors contributed equally to the preparation of this article.

Declaration of competing interest

The authors declare no conflicts of interest.

Funding source

This study didn't receive any specific funds.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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How to cite this article:
Janan Sabah Ali and Faris Ali Mustafa. (2025). 'Active workplace: Architectural interventions for reducing sedentary behavior and promoting stair use', Al-Qadisiyah Journal for Engineering Sciences, 18(4), pp. 352- 446. `https://doi.org/10.30772/qjes.2025.158353.1524`