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Investigating the Relationship between Energy Consumed in Activities and the Spatial Enclosure Component to Improve the Quality of Architectural Design Process*

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ABSTRACT

A high-quality design of space-based activity is one of the major concerns in architectural planning, and for this, many standard spatial references have been codified to help coordinate both functions and structures. The level of the enclosure, one of the components affecting the definition and understanding of space, plays an effective role in organizing space and its utility by emphasizing dimensions fit and the correct distance of its constituent elements. However, the level of enclosure and an explanation of relevant issues have been less focused attention in architectural studies, with the concepts of this field found only in urban engineering. This study aimed to create a quantitative method to estimate the optimal spatial structure dimensions and the level of enclosure. Also, the study sought to examine the relationship between the mass-space system and activity energy. This research was applied in terms of objective and correlational in terms of nature and method. Consistent with the research process, data were quantitative, and the sources which estimated the energy consumption of the activities were used. Available dimensional standards were also used to determine the optimal size of the spaces under study. Since this study examined such factors as space volume, area, and the number of users of the space, and their relationship with the number of calories consumed in that space, the relationship between calories consumed per minute and area with the component of space volume was 98% and the relationship between calories consumed per minute and area 92%. Furthermore, quantitative formulas to recover space volume and area to calculate the calories consumed in space were demonstrated in this study.

Keywords: Level of the Enclosure, Spatial Utility, Energy Consumption Activity, Regression Analysis.

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1. STATEMENT OF THE PROBLEM

From a scientific and philosophical point of view, the concept of space shows that it tends to be a subjective phenomenon. The empirical understanding of space implies that space is not, per se, an object, rather it is a relationship between objects, a seat of objects, or radiation of objects; as an artwork of architecture, space is interpreted by such terms as enclosed, sacred, transparent, personal, and collective involving mental and perceptual aspects. An architectural space is generally referred to as the distance between buildings materials aimed at creating a haven for human activities, with special qualities attached to it (Falahat & Shahidi, 2015). The distance between the physical elements of a building creates a sense of enclosure which has a direct effect on the behavior. Enclosed spaces strengthen social relations while lack of enclosure keeps people from each other. An accurate understanding of the elements causing enclosure greatly contributes to assessing the desirability of the space in the analysis phase. Each element or phenomenon in space distinguishes it and gives it a spatial identity. This element or phenomenon can be characterized by physical, social, or subjective features. Considering the extent to which force affects each of the dimensions, space is identified by emphasizing those features (Seydian & Abafat Yeganeh, 2007). An investigation of the architectural physical-perceptual structure helps create a context for users to understand architecture goals and significance by being present in space. On the other hand, the exact match between the structure elements creates a space wherein meanings can be perceived. Movement in space, both internal or external as created by the presence of the structure, helps users better understand architecture. The physical-functional structure also refers to the activities happening in space and suggests a proportionate structure that is conducive to specific activities (Falahat & Shahidi, 2015).

D.K. Ching maintains that space is defined by four vertical levels completely enclosing a place. For him, the four levels can define the visual and spatial limits that organize the mass in itself with the surrounding buildings belonging to the interior limits, activating and the enclosed space. On the other hand, Rogers Transik defines space or counter-space by mass and volume. Space is read when conflicting with its context (Negin Taji, 2011). As stated, despite the importance of spatial enclosure, scant studies have concerned this area with most of them focusing on urban engineering. Moreover, considering the appropriate potential of the enclosure coefficient as regards its qualitative components, a wide range of findings were reported in the qualitative area with no special efforts made in this field.

This study was aimed at developing a quantitative index for an appropriate enclosure level of each space by looking at the activity designed for it. Using the developed index, the spatial utility component will also be affected and improved. Moreover, considering two issues of space area and volume in defining the level of enclosure, the specialized architectural design community will, as per the results, find it less urgent to refer to spatial dimensional standards.

This study assumed that various space activities can be categorized by calculating such components as energy and oxygen consumed; also considering features of activities in each space helps predict the spatial and physical dimensions of that space. The research aimed to answer the following questions:

- Is there a significant relationship between the mass-space system and the energy of the activities consumed in it?
- What are the components of this meaningful relationship?
- Can this mechanism be used as an architectural machine as consistent with common definitions?

2. LITERATURE REVIEW

The index quality of any man-made place is referred to as enclosure, with its spatial features characterized by the way it is enclosed. The property of a man-made place is largely determined by its openness. The hardness and transparency of limits cause the space to appear isolated or part of a whole (Nurberg Schultz, 2009). The enclosure is seen as one of the qualities that play a determining role in defining spaces; in fact, it is the enclosure that defines the context of space as a platform for the occurrence of other events.

By enclosure it is meant a space confined by its walls, feeling as if one is inside a container. The enclosure is shown by some levels originating from at least two basic factors:

A) Ratio of wall height to the floor

B) Continuity on the space wall

Of course, other factors such as color, texture, type, and shape of wall and floor materials also have a direct effect on the sense of space enclosure (Pakzad, 2006, p. 133).

The Dehkhoda dictionary defines "enclosed" as meaning confined, besieged, and entangled. Architecture and urban planning concepts refer to an enclosed space as an area surrounded by physical or symbolic elements. Put it differently, if space is somehow confined in a structure, an enclosed space is created (Seydian & Abafat Yeganeh, 2007). Generally speaking, the level of the enclosure can have a direct effect on human behavior. Enclosed spaces strengthen social ties, and a lack of enclosure keeps people from each other. An accurate perception of the elements that cause enclosure will greatly help assess the desirability of the space in the analysis phase. Having said this, to achieve an attractive place, space must be well enclosed (Shams & Nik Pima, 2012). As suggested, the spatial enclosure component and relevant values in studies of the human scale as well as proportions are focused attention. One of the important features of spaces of a human scale is enclosure. A space enclosed by the human soul is consistent with the human spaces. According to studies, public space enclosure not only facilitates access to the human scale but is also very critical in creating a sense of security for people.

This holds for different spatial scales; for example, in a review of design and residential spaces principles and methods in Iran, Tavasoli concluded that if space was not enclosed properly, an attractive public place or urban space would be lacking. He argued that an enclosed space was characterized by the creation of a sense of place. Enclosed space creates a more secure environment than an abandoned and disorganized space (Shahabi Nejad, Aboie, Ghalenoei, & Mozafar, 2014). The concept of the enclosure was also studied and used in research on angles and isovists-based studies. The relationship between the elements causing spatial enclosure along with mobility and its effect on the viewer's perception of space was addressed by Betty. Here in this study, two simple geometry hypotheses and three real examples using Tate Gallery in London, Regent Street, and Downtown and Northampton were employed which found that, although spatial morphology can be understood from initial geometric elements such as corridors Streets, rooms, and squares, isovist-based studies demonstrated that spatial understanding and mind mapping will ultimately be created out of the interactive enclosure and mobility in space (Batty, 2001).

As mentioned, the spatial enclosure was positively represented in spatial perception. Turner et al. studied the isovists and visual graphs of several cases studied to conclude that the properties of spatial enclosure pertained to spatial perceptions, such as finding a way in, mobility, and use of space (Turner, Doxa, O'Sullivan & Penn, 2001). As demonstrated, the spatial enclosure component contributes less to the study of architectural theory with the relevant concepts developing in the field of urban research. For example, Carmona maintained that the level of enclosure and, consequently, its limits were related to the width of the space and height of the enclosing walls (Haghirian, Sajjadzadeh, & Karimi, 2016). Ashi Hara also extended this concept to the urban scale, explaining the D/H, W/D ratio in the city as follows: The D/H = 1 ratio can be used as a median for comparing spatial quality depending on the ratio being more than or lower than 1. When this ratio is greater than 1, space has the openness and expands, and when it exceeds 2, it incrementally expands into a wider space, very open and infinite. When this ratio is less than 1, space first appears to be compact and familiar and then becomes cramped and suffocating. When the ratio stands at 1, balance is made (Yoshi Nobashi, 2012, p. 69). Generally, the concept of enclosure in any space is a parameter affected by the elements covering that space and the way dimensions are placed. This parameter is directly affected by the area and volume of the space and the length to width and to height ratios which make changes to it. Considering the significant role of enclosure in defining human scales of space, determining view angles, and also its effect on improving the quality of human interactions, space enclosure criteria will cover a significant part of the primary principles of space design. Looking at various relevant researches, it is seen that in most studies, the role of the spatial enclosure as an independent variable on other issues has been studied while its definition, the way it is created and measured are less focused attention. Accordingly, it is imperative to make efforts to develop a theoretical framework to define the component under study.

3. METHODOLOGY

The present study was applied in terms of objective and descriptive in terms of data collection. Descriptive or non-experimental research can be divided into five categories of the survey, correlation, Ex-Post Facto, action research, and case study. This research was a correlative study as the research aimed to measure the correlation between the defined variables. Because the research was aimed at predicting dependent variables based on the changes to independent variables, dependent variables were categorized into criterion variables and independent variables as predictive variables. The hypothesized correlation was measured by regression analysis; since in the research process, a criterion variable was examined based on several predictive variables, multiple regression was applied. Regression is a method to explore experimental relationships between an independent and dependent multi-binary class as well as continuous variables (McCullagh & Nelder, 1989, p. 141). This technique aims to estimate a function of independent variables called regression function. Under specific conditions, this analysis can be used to infer excellent relationships between independent and dependent variables (Bazargan Lari, 2011, p. 51).

There are two primary approaches to spatial dependence and regression framework; one seeks to create a more complex integrated model such as a self-reducing structure for the spatial structure (Anselin, 1988), and the latter aims to design a spatial model to increase the interval between the sample points under study. Therefore, the above method can be used as a reasonable tool to remove spatial self-correlation, and to use rational design for the sample under study, thus creating an ideal balance between the two aspects (Xie, Huang, Claramunt, & Chandramouli, 2005).

Unknown parameters are represented by β and indicate a scale or vector. Independent variables are represented by X and dependent variables by Y. As suggested, the relationship between the variables and the unknown parameter, as shown from Equation 1, is as follows.

Equation 1: The Proposed Equation between Independent and Dependent Variables

$$Y \approx f(X, \beta)$$

The type of research data was quantitative and they were collected via library studies. Considering the objectives and hypotheses defined for this research, the proposed variables system is defined as follows:
Independent variable: Type of activities, level of calories consumed by activities.
Dependent variable: Spatial dimensions and size, level of spatial enclosure.
Moderating variable: Weight of space users, peoples' age, and their gender.
Intervening variable: Psychological state of space users, their physical capacity.

To obtain the values of the independent variable, which represent the level of calories consumed by the activities exercised in the spaces under study, library sources and documents indicating the activity energy were studied. As shown in Table 1, these sources cover a wide range of activities, e.g., from daily activities to sports activities, accurately taking into account the caloric consumption from each activity as relative to peoples' weight. Looking at a large amount of data, the activities considered for middle-aged men was optional being consistent with the spaces where their dimensional standards are available.

Table 1: Calories Consumed by Various Physical Activities

Activity by Weight	59	62	65	68	71	74	77	80	83	86	89	92
Competition Badminton	8.6	9.0	9.4	9.9	10.4	10.8	11.2	11.6	12.1	12.5	12.9	13.4
General Cooking	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2
Competition Basketball	8.7	9.2	9.6	10.1	10.5	10.9	11.4	11.8	12.3	12.7	13.1	13.6
Billiard	2.5	2.6	2.7	2.9	3.0	3.1	3.2	3.4	3.5	3.6	3.7	3.9
Competition Boxing	13.1	13.8	14.4	15.1	15.8	16.4	17.1	17.8	18.4	19.1	19.8	20.4
General Carpentry	3.1	3.2	3.4	3.5	3.7	3.8	4.0	4.2	4.3	4.5	4.6	4.8
Cleaning	3.4	3.6	3.8	3.9	4.1	4.3	4.5	4.6	4.8	5.0	5.2	5.3
Stand-Up Drawing	2.1	2.2	2.3	2.4	2.6	2.7	2.8	2.9	3.0	3.1	3.3	3.3
Eating While Sitting	1.4	1.4	1.5	1.6	1.6	1.7	1.8	1.8	1.9	2.0	2.0	2.1
Electrical Work	3.4	3.6	3.8	3.9	4.1	4.3	4.5	4.6	4.8	5.0	5.2	5.3
Cleaning The Warehouse	8.0	8.4	8.8	9.2	9.6	10.0	10.4	10.8	11.2	11.6	12.0	12.4
Filed Hockey	7.9	8.3	8.7	9.1	9.5	9.9	10.3	10.7	11.1	11.5	11.9	12.3
Handball	8.5	9.0	9.4	9.8	10.3	10.7	11.2	11.8	12.0	12.5	12.9	13.3
Lying Down Comfortably	1.3	1.4	1.4	1.5	1.6	1.6	1.7	1.8	1.8	1.9	2.0	2.0
Welding	3.1	3.2	3.4	3.5	3.7	3.8	4.0	4.2	4.3	4.5	4.6	4.8
Squash	12.5	13.1	13.8	14.4	15.1	15.7	16.3	17.0	17.6	18.2	18.9	19.5
Ping Pong	4.0	4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.8	6.1	6.3
Sewing/ Ironing	3.7	3.8	4.0	4.2	4.4	4.6	4.5	5.0	5.1	5.3	5.5	5.7
Electric Typewriting	1.6	1.7	1.8	1.8	1.9	2.0	2.1	2.2	2.2	2.3	2.4	2.5
Competition Volleyball	8.7	9.1	9.5	10.0	3.6	3.7	3.9	4.0	4.2	4.3	4.5	4.6
Judo	11.5	12.1	12.7	13.3	13.8	14.4	15.0	15.6	16.2	16.8	17.4	17.9
Competition Tennis	8.7	9.1	9.5	9.9	10.2	10.6	11.1	11.5	11.9	12.4	12.8	13.2
Billiard	2.5	2.6	2.7	2.9	3.0	3.1	3.2	3.4	3.5	3.6	3.7	3.9

(William, Frank, & Victor, 2013)

Assuming the physical and mental health of space users, and referring to the existing dimensional standards for spaces understudy, dependent variable values for the selected activities are seen in Table 1. Length, width, height, area, and volume are the dimensional components for the activities in Table 2. Moreover, in proportion to the number of people participating in sports activities and also considering the users of spaces selected, the level of calories consumed by each person was multiplied by the number of people with the total level of calories consumed per minute for space also estimated.

Table 2: Comparison of Standard Space Dimensions and the Number of Calories Consumed

Type of Sport	Length	Width	Height	Area	Space Volume	Consumed Calorie (One Minute)	Number of Users	Total Calories Consumed
Squash	9.75	6.4	5.7	62.4	355.68	15.1	2	30.2
Badminton	13.4	5.18	9.1	69.412	631.64	10.4	2	20.8

Type of Sport	Length	Width	Height	Area	Space Volume	Consumed Calorie (One Minute)	Number of Users	Total Calories Consumed
Basketball	28.	15	9	420	3780	10.5	10	105
Boxing	6.1	6.1	7	37.21	260.47	15.8	2	31.6
Tennis	23.8	8.2	9	195.16	1756.44	10.2	2	20.4
Ping pong	14	7	2.7	98	264.6	4.8	2	9.6
Judo	10	10	7.5	100	750	13.8	2	27.6
Wrestling	12	12	7	144	1008	13.8	2	27.6
Volleyball	18	9	9	162	1458	3.6	12	43.2
Indoor Hockey	40	20	7.6	800	6080	11	12	132
Handball	40	20	9	800	7200	10.3	14	144.2
Billiard	3.7	1.9	2.7	7.03	18.9	3	2	6
General Cooking	4.5	3.5	2.8	15.75	44.71	3.2	2	6.4
Eating	3.75	3.25	2.5	12.18	30.46	1.6	6	9.6
Sitting Slowly	4.87	3.81	2.2	18.57	40.86	1.5	8	12
Getting up Slowly	3.6	3.05	2.5	10.98	27.45	1.9	10	19
Drawing/ Mapping	3	2.4	2.5	7.2	18	2.6	1	2.6
Interior Design Sketches	3	2	2.5	6	15	2.4	1	2.4
Typing	3.05	1.95	2.4	5.94	14.27	1.9	1	1.9
Writing while Eating	2.9	2.45	2.4	7.105	17.052	2.1	1	2.1
Sewing	2.15	1.8	2.5	3.87	9.675	2.9	1	2.9
Cutting	2.15	1.8	2.8	3.87	10.83	2.3	1	2.3
Hand Sewing	2.15	1.8	2.4	3.87	9.28	3.2	1	3.2
Machine Sewing	4.6	2.5	2.5	11.5	28.75	4.4	2	8.8
Ironing	2.15	1.8	2.5	3.87	9.67	4.5	1	4.5
Welding	15	7.5	3.5	112.5	393.75	4.6	3	13.8
Hitting and Piercing	18.75	10	3	187.5	562.5	3.7	4	14.8
Woodturning	18	15	3	270	810	4.1	5	20.5

After creating a comparison table for independent and dependent variables, their correlation was investigated through multiple regression analysis. As stated earlier, there are different methods for regression analysis. In this research, a multiple regression model was used. Using Minitab 16 software and regression analysis, the closest function of changes pertaining to the variables studied was obtained. The functions created by the software determined the correlation of the variables as well as the extent to which they affected each other. These relations will help estimate the optimal dimensions of the spatial structure and level of the enclosure by such components as calories consumed and the number of people present in space.

4. DISCUSSION AND ANALYSIS OF FINDINGS

To meet the objectives of the research, the distinct relationship between area and space, as two quantitative components affecting the level of spatial enclosure, with the level of energy consumption in selected spaces and the equations between the variables was calculated. Knowledge of the area of each space as a factor determining its dimensional relationship in two dimensions of form and function greatly contributed to the optimal design of that space. In this part of the research, considering the studies performed on the area of several spaces understudy, calculated from standard dimensional sources and also using energy consumption of the activities in those spaces (specific in the table), the proposed equation between independent and format-dependent variables $Y \approx f(X, \beta)$, was obtained by the software. This equation (Equation 2) contains a coefficient for the defined variable and a constant number.

Relationship 2. The Proposed Equation between Area and Consumed Calorie Variables

A (Calories Consumed Per minute) 5.60 + -9.37 = Area

To examine the correlation between the variables, the following hypothesis is used to test the hypotheses:

$$\begin{cases} H_0: b = 0 \\ H_1: b \neq 0 \end{cases}$$

Table 3: Adequacy Index of the Model for the Relationship between Calories Consumed Per Minute and the Space Volume

Correlation Coefficient	Coefficient of Determination	Modified Coefficient of Determination	Error Standard Deviation	Durbin-Watson Value
0.961	0.924	0.916	0.50	1.52

Predictors: (Constant), Calories Consumed Per Minute Dependent Variable: Area

Pearson correlation between independent (calories consumed per minute) and dependent (area) variables was 0.96. The coefficient of determination was 0.92, suggesting that 92% of the area changes can be explained by the component calorie consumed per minute. Also, the Durbin-Watson value used in the regression to test the error independence was approximately 1.52. If the value ranges from 1.5 to 2.5, using regression (which is the case here) is allowed.

Table 4: Table of Significant Correlation of Calories Consumed Per Minute and Area

Sources of Variations	Sum of Squares	Freedom Degree	Mean Squares	F	Sig.
Regression	806128	1	806128		
Residuals	66569	10	6657	121.10	0.000
Total	872696	11			

Predictors: (Constant), Calories Consumed Per Minute Dependent Variable: Area

Because the significance level was less than the error value of 0.05, so the above table indicates the regression was significant at the 0.95 level; in other words, the effect of the independent variable on the dependent variable was found to be significant with the H_0 hypothesis being rejected and H_1 confirmed. Put it simply, there is a correlation between calories consumed per minute and area.

Table 5: Relationship between the Components of Calories Consumed Per Minute and Area

Model	Non-standard Coefficients		Standard Coefficient	T	Sig.
	B	Standard Error	Beta		
Constant	0.8	34.62		-1.10	0.299
Calories Consumed Per Minute	5.60	0.5089	92.48	11.00	0.00

Dependent Variable: Area

Considering the following linear regression equation:

(Calories consumed per minute) 5.60 + -9.37 = Area

The positive sign indicates a direct relationship between the component of calorie consumed per minute and the area. Looking at the p (significance level), the value reported for the independent variable of calorie consumed per minute, this variable has a significant discrepancy with zero ($b \neq 0$) and a coefficient of 0.489 suggests that for one unit increase in the independent variable of calories consumed per minute, the area variable will change and increase by 0.489. The linear regression result indicates that the component of calories consumed per minute was correlated with the area.

The standardized regression coefficient or Beta was 0.92, indicating the relationship between the independent variable (calories consumed per minute) and the dependent variable (area). Using this formula, and considering the level of energy used for the expected activities in the desired design space, one would better understand the area of the space.

Concerning the estimation of the space volume as the dependent variable, a function was selected from among the extracted relationships that indicates the relationship from the changes between the two variables of the number of people and the level of calories consumed per minute and the space volume (Equation 3).

To estimate the space height, Equation 2 can be used, which indicates the proposed equation between the variables of area and calories consumed; in the meantime, by dividing these two factors, the estimated height of the desired space can be calculated.

Relationship 3. The Proposed Equation between the Variables of Volume, Number of People, and Calories Consumed Per minute

(Calories Consumed Per Minute) +141 (Number of People) 441 + 1830 = Space Volume

Table 6: Adequacy Index of the Model on the Relationship between Calories Consumed Per Minute and the Number of People with the Volume of Space

Correlation Coefficient	Coefficient of Determination	Modified Coefficient of Determination	Error Standard Deviation	Durbin-Watson Value
0.888	0.790	0.744	0.1223	1.776

Predictors: (Constant), Calories Consumed Per Minute and Number of People Dependent Variable: Space Volume

Pearson correlation between independent (calories consumed per minute and number of people) and dependent (space volume) variables was 0.888. The coefficient of determination was 0.79, suggesting that 79% of the area changes can be explained by the component calorie consumed per minute and the number of people simultaneously. Also, the Durbin-Watson value used in the regression to test the error independence was approximately 1.776. If the value ranges from 1.5 to 2.5, using regression (which is the case here) is allowed.

Table 7: Significance Test of Correlation of Calories Consumed Per Minute and Number of People with the Volume of Space

Sources of Variations	Sum of Squares	Freedom Degree	Mean Squares	F	Sig.
Regression	50800354	2	25400177		
Residuals	13674627	9	1497381	16.96	0.001
Total	64276781	11			

Predictors: (Constant), Calories Consumed Per Minute and Number of People Dependent Variable: Space Volume

Because the significance level was smaller than the error value of 0.05, the above table indicates the significance of regression at 0.95. In other words, the effect of the independent variable on the dependent variable was significant and the H_0 hypothesis is rejected while H_1 is confirmed. Put it differently, the calories consumed per minute and the number of people are correlated with space volume.

Table 8: Relationship between the Components of Calories Consumed Per Minute and the Number of People with the Space Volume

Model	Non-standard Coefficients		Standard Coefficient	T	Sig.
	B	Standard Error	Beta		
Constant	-1830	1116		-1.64	0.001
Number of People	440.97	75.81	0.79	-5.82	0.00
Calories Consumed Per Minute	141.44	87.41	0.71	-1.62	0.014

Dependent Variable: Space Volume

Considering the following linear regression equation:
(Calories Consumed Per Minute) +141 (Number of People) 441 + 1830 = Space Volume = Area
The negative sign indicates an indirect relationship between the component of calorie consumed per minute and the number of people with the space volume. Looking at the p (significance level), and the value reported for the independent variable of calorie consumed per minute, this variable has a significant discrepancy with zero ($b \neq 0$) and a coefficient of 0.441 suggests that for one unit increase in the independent variable of calories consumed per minute, the area variable will change and increase by 0.441. also, 0.441 suggests that for a unit increase in the independent variable of calories consumed per minute, the variable of space volume will change or increase by 0.141. The linear regression result indicates that the component of calories consumed per minute was correlated with the number of people with the space volume.
The standardized regression coefficient or Beta was 0.79, indicating the relationship between the independent variables (calories consumed per minute and the number of people) and the dependent variable (space volume).
As stated earlier, the height of the space understudy can be calculated by Equations 2 and 3; however, the calculation of the mentioned spatial structure from another highly accurate regression function was also possible. Equation 4 illustrates the equation proposed for the variables of volume, area, and calories consumed per minute. Considering dimensional standards and the proposed area for uses in standard reference books, the component of the area along with the level of calories consumed in the activity, can help determine the extent of space enclosure, thus compensating for the space desirability lost from a quantitative architectural view.
Equation 4. Proposed Equation for the Variables of Volume, Area, and Calories Consumed Per Minute
Calories Consumed Per Mnute 10.3 + 193- = Volume of Space

Table 9: Adequacy Index of the Model on the Relationship between Calories Consumed Per Minute and Area with the Volume of Space

Correlation Coefficient	Coefficient of Determination	Modified Coefficient of Determination	Error Standard Deviation	Durbin-watson Value
0.993	0.987	0.744	0.3086	1.895

Predictors: (Constant), Calories Consumed Per Minute and Area of the Dependent Variable: Volume of Space

Pearson correlation between independent (calories consumed per minute and area) and dependent (space volume) variables was 0.993. The coefficient of determination was 0.98, suggesting that 98% of the space area changes can be explained by the component calorie consumed per minute and the area simultaneously. Also, the Durbin-Watson value used in the regression to test the error independence was approximately 1.895. If the value ranges from 1.5 to 2.5, using regression (which is the case here) is allowed.

Table 10: Test of Significant Correlation of Calories Consumed Per Minute and Area with the Volume of Space

Sources of Variations	Sum of Squares	Freedom Degree	Mean Squares	F	Sig.
Regression	63419644	2	31709822		
Residuals	857138	9	95238	332.96	0.00
Total	6427678	11			

Predictors: (Constant), Calories Consumed Per Minute and Area of the Dependent Variable: Volume of Space

Because the significance level was smaller than the error value of 0.05, the above table indicates the significance of regression at 0.95. In other words, the effect of the independent variable on the dependent variable was found to be significant and the H_0 hypothesis is rejected while H_1 is confirmed. Put it differently, calories consumed per minute and area were found to be correlated with the space volume.

Table 11: Relationship between the Components of Calories Consumed Per Minute and Area with the Space Volume

Model	Non-standard Coefficients		Standard Coefficient	T	Sig.
	B	Standard Error	Beta		
Constant	-1.193	138.6		-1.39	0.001
Calories Consumed Per Minute	10.277	6.970	0.95	1.47	0.004
Area	6.816	1.196	0.92	5.70	0.00

Dependent Variable: Space Volume

The linear regression equation is as follows:

Area 6.82 + Calories Consumed Per Minute 10.3 + 193- = Volume of Space

A negative sign indicates an indirect relationship between the components of calories consumed per minute and the area with the volume of space. Considering the p (significance level) of the value reported for the independent variables of calorie consumption per minute and area, these variables have a significant discrepancy with zero ($b \neq 0$) while a coefficient of 10.3 suggests that for one unit increase in the independent variable of calories consumed per minute, the variable of space volume will change and increase by 10.3. The coefficient of 6.82 also indicates that for a one-unit increase in the independent variable of area, the variable of space volume will change and increase by 6.82. The linear regression demonstrated that the components of calories consumed per minute and area were correlated with the space volume.

The standardized regression coefficient or Beta was 0.95 and 0.92, indicating the relationship between the independent variables (calories consumed per minute and area) and the dependent variable (space volume).

5. CONCLUSION

According to the equations developed for the relationship between the variables in this study, it was found that 92% of changes to the area could be explained by the component of calories consumed per minute, while the mentioned percentage for the dependent variable decreased to 79%. The reason for the reduction was the addition of the height parameter to the variable of volume, affecting the accuracy of the equation. In Equation 4, the changes in the volume-dependent variable, as compared to the variables of area and calories consumed per minute, were predicted to significantly increase to reach 98%.

To answer the first question of this study, one would argue that the high rate of changes in the components under study suggested a significant relationship between the mass-space system and the energy consumed in space activities, helping estimate spatial dimensions and thus its level of enclosure. The components were determined by the number of users of the space, the level of calories consumed in the activity, and the dimensional factors of volume which were selected as needed and used in the relationships extracted.

To answer the other question, the concept of architectural machine, implying the essential, inclusive, fast, and reproducible mechanism (Ziaei, Naghizadeh, & Mokhtabad Amrei, 2017), can be used to recover spatial equations as an architectural machine. Because space area and volume directly affect the level of spatial enclosure, recovering equations that proposed space area and volume using activities and its types will affect the way the component of the enclosure is determined. Extracted spatial equations in this study can be employed as a design machine or part of an all-out machine. This means that the mechanism created can be utilized in designing spatial planning to determine the spatial dimensions. Thus, one can use the advantages of the machine-thinking mechanism, i.e., speed, iteration, and balance in spatial justice. This research tested the authenticity of the hypotheses and predicted the spatial structural dimensions by the level of energy used in space.

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