

# STRUCTURE OF SPACE-ACTIVITY RELATIONS IN HOUSES

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## Introduction

It is generally observed that there is a relationship between place and behaviour, and that a misfit between these creates discomfort, tension and a sense of unhappiness in users. Various design methods have been developed, based on the assumption that there are relationships between architectural spaces and the activities that take place in these spaces (Cousin; Bullock, 1970 and 1971).

More often than not, such methods have been based on the easily quantifiable aspects of activities, such as, distance walked, rather than more pertinent behavioral aspects. In addition, neither the concept of architectural space nor that of activity have been given a precise definition, so that their interrelationship, which constitutes the main assumption of these methods, can not be investigated sufficiently. Thus, it becomes very difficult to interpret the validity of results obtained through the use of these methods.

Being an attempt at clarifying some of the concepts and methods involved in the problem, this paper presents a set theoretic approach to the definition of the concepts of architectural space and activity and a structural examination of their relationship in sample houses (Baykan). The purpose of the study is to try to define the concepts of architectural space and activity as members of specific sets and to investigate the structure of open statements such as "*space s provides the setting for activity a*" or "*activity a takes place in space s*" in houses. The major portion of the paper is devoted to the structural analysis; the definitions of space and activity are restatements of those available in the literature and no extensive discussion is given related to these definitions.

## Architectural Space

The concept of space is a human construct involving notions of position, orientation and dimension, it is widely used not only in the analysis of physical entities and phenomena but also in human problems of psychological and social import. In addition to influencing the way man perceives space, the concept also forms his attitude towards it.

The spaces that form descriptions of man's environment have been variously called pragmatic space, existential space, perceived space, conscious space and logical space,

depending on man's consciousness of it (Norberg-Schulz; Relph). Architectural space is one such space, created and/or used by man to fulfil his basic needs such as shelter and accommodation of activities and is entered by him. It is defined by physical as well as perceptual elements. One can say that architectural space is an artistic and expressive space that "express[es] the structure of his world as a real *imago mundi*" (Norberg-Schulz, 11). The spaces that man creates are tied, at the same time, to his space schemata: space schemata are formed according to existing architectural spaces, but also influence the formation of new architectural spaces. Thus, we may say that architectural space is the concretization of man's existential space.

Various parallels exist between existential space and architectural space. Just as places are the centers of purpose, intentions, meaning, and serve to accommodate specific activities and social interactions, architectural spaces have the same characteristics. In addition, whereas place has a topological quality, independent of dimension and position, architectural space has geometric properties, involving dimensions and measure.

Taking these considerations into account, we can say that the following are important factors in the definition of architectural space:

- a. Physical properties.
- b. Human perception.
- c. Function or use.

A definition for architectural space, which takes into account these factors, may be given through the concepts of set theory. In doing this, we shall consider as the universe of discussion the set  $U$  of all spaces  $s$  that can be defined physically in terms of dimension, measure and connectivity. The approach that we use in defining architectural space will be to define special subsets  $U_i$ ,  $i = 1, 2, \dots$ , of the universe which have specific characteristics and to define architectural space as an intersection of these subsets.

1. Man enters and uses all architectural spaces for various purposes. A necessary condition for this is that the space is habitable by man. Thus spaces such as the void of the universe, silos or water tanks full of media other than air may not qualify as architectural space. Let  $U_1$  be the set of all spaces possessing this property:

$$U_1 = \{ s \mid s \text{ is a space that is entered and used by man} \}.$$

2. All architectural spaces are bounded by a surface that forms the base (or floor) of that space. This surface is commonly one that allows man's movement with minimum change in his potential energy; alternatively, one that provides neutral equilibrium with respect to gravity. Thus, let

$$U_2 = \{ s \mid s \text{ has a base floor} \}.$$

3. Architectural space has boundaries, either physical and material or not, that allows man to perceive its "interior" as different from its "exterior." Man perceives these boundaries as defining the space according to his space schemata. These schemata being mainly visual, being inside is mainly a visual phenomenon. Thus, architectural space needs to be compact and centralised so that it is possible to see the

whole space from some central focus. According to the boundaries perceived, however, spaces may be classified as open or closed, positive or negative, etc. Thus,

$$U_3 = \{ s \mid s \text{ has an inside that is perceived as being distinct from its outside} \}.$$

4. The size of an architectural space varies between definite limits. The lower limit is that of a cell that a single human being can enter. The upper limit may be set at the inside of a large domed mosque or a sports hall, or public open spaces such as squares and stadia. Thus,

$$U_4 = \{ s \mid s \text{ has a size that varies between determinate limits} \}.$$

5. Architecture comprises what man selects from nature to serve his needs or what he builds himself to that end. Thus, architectural spaces are those that make conditions favorable for man by providing shelter, privacy, or by defining symbolic or meaningful places.

$$U_5 = \{ s \mid s \text{ is created or adapted by man to suit his needs} \}.$$

In order to qualify as an architectural space, a space must satisfy all of the conditions discussed above. Thus, architectural space may be defined as follows:

**DEFINITION** If for any space  $s$ ,  $s \in U_i$  for all  $i = 1, 2, \dots, 5$  as defined above, then  $s$  is an architectural space.

We note that according to this definition, the set of architectural spaces  $S$  may be written

$$S = \bigcap_{i=1}^5 U_i$$

## Activity

In human beings, all uses of energy and responses to stimuli constitute behavior. Behavior occurs at many different levels, all of them linked. While partially independent as events on different levels, they are also partially interdependent as events of a larger system. Many units of behavior have been identified including reflex, actone, action, molecular behavior, molar unit, group activity, behavior episodes, and standing patterns of behavior.

An activity is a combination of these types of behavior and possesses certain characteristics. In the first instance, we may call as behavior units those behavior types which possess the characteristics discussed below. We go on to qualify those behavior units having definite characteristics as activities.

1. Behavior units occur independently of the observer, according to their internal organisation. They may arise as a response to stimuli but may also occur

independently of them. These two modes of occurrence are complementary. We define here the set of behaviors

$$B_1 = \{ b \mid b \text{ is a self-generated unit} \}.$$

2. Behavior units occur in relation to the environment and become part of their environment. They take place in time and space, and they can be located in it. Thus,

$$B_2 = \{ b \mid b \text{ has a time-space locus} \}.$$

3. Each stratum of organisation possesses unique properties of organisation. A behavior occurring at a level forms the context within which those at lower levels acquire meaning. The internal pattern at a specific level is determined by the elements at a lower level. Thus,

$$B_3 = \{ b \mid b \text{ has an unbroken space-time boundary separating an internal from an external pattern} \}.$$

4. Some behaviors develop unconsciously and do not have any meaning for people, whereas others occur in relation to parts of the world with some kind and degree of meaning for the people involved. For example, breathing has no meaning for a person in relation to his environment whereas hosting a dinner party does. Thus,

$$B_4 = \{ b \mid b \text{ is a meaningful behavior} \}.$$

5. Behavior may have a specific purpose or not. We define

$$B_5 = \{ b \mid b \text{ is goal-directed} \}.$$

6. A person may be involved in several different behaviors at the same time, but may also be engaged in a behavior that engages his whole personality. For example, walking and thinking are behaviors that may occur simultaneously whereas taking a walk, as the composite of all the subsidiary behaviors it involves, engages the whole person. Thus,

$$B_6 = \{ b \mid b \text{ engages the whole person} \}.$$

Based on these sets, we now define a behavior unit as follows:

**DEFINITION** If for any behavior  $b$ ,  $b \in B_i$  for all  $i = 1, 2, \dots, 6$  as defined above, then  $b$  is a behavior unit.

We note that according to this definition, the set of behavior units  $E$  may be written

$$E = \bigcap_{i=1}^6 B_i$$

An interesting property of the set of behavior units E is that some members of this set include others, and thus are at a higher level of hierarchical order than others. We may distinguish three hierarchical levels in this set which we shall label the levels N-2, N-1, and N.

Behavior units at the level N-2 are called behavior episodes. "Like crystals and cells, behavior episodes also have as clear a position in the hierarchy of behavior units, as the former have in the hierarchies of physical and organic units." (Barker, 146) The attributes of behavior episodes are constancy of direction, equal potency throughout their parts and limited size range. For example, taking vegetables out of the refrigerator, washing them and peeling potatoes are three separate behavior episodes.

The N-1 level in the hierarchy of behavior units is made up of units which are called action systems. These are sequences of behavior episodes organised as a meaningful and purposeful pattern. Cooking beans or making a salad are examples of action systems.

Activities, at the N level, consist of action systems that are for the same purpose. Preparing a meal, for example, is an activity. Activities have been observed to possess the following characteristics:

1. An activity has unique characteristics that persist when the participants change. A dinner is still the same activity even though the host and the guests may change. Thus,

$$A_1 = \{ e \mid e \text{ is an extra-individual pattern of behavior} \}.$$

2. Personal, social and public activities take place with the participation of a certain number of people, their number being defined according to the nature of the activity. For example, entertaining guests is an activity that has participants with the roles of host and guests.

$$A_2 = \{ e \mid e \text{ occurs with the participation of people with definite roles} \}.$$

3. Activities are behavior units that are repeated in time. They may be scheduled formally or informally, or they may occur serially.

$$A_3 = \{ e \mid e \text{ has a repetitive character} \}.$$

In order to qualify as an activity, a behavior unit must satisfy all of the conditions discussed above. Thus, activity may be defined as follows:

**DEFINITION** If for any behavior unit e,  $e \in A_i$  for all  $i = 1, 2, 3$  as defined above, then e is an activity.

We note that according to this definition, the set of activities A may be written

$$A = \bigcup_{i=1}^3 A_i$$

In reality, an activity is a name given to combinations of action systems found within the hierarchical structure of the set A.

### Spaces and Activities in Houses

The spaces (henceforth used to denote architectural space only) and the activities discussed in this paper have been identified from the life experience of the main author who personally lived or stayed overnight in the nine houses included in this study (Baykan). Of these, two, including one shown in Figure 1 and which constitutes the example used throughout this paper, were first floor flats in two storey buildings in a garden. The ground floors of these houses are used for storage and as a house, respectively. The seven other houses studied were apartment flats.

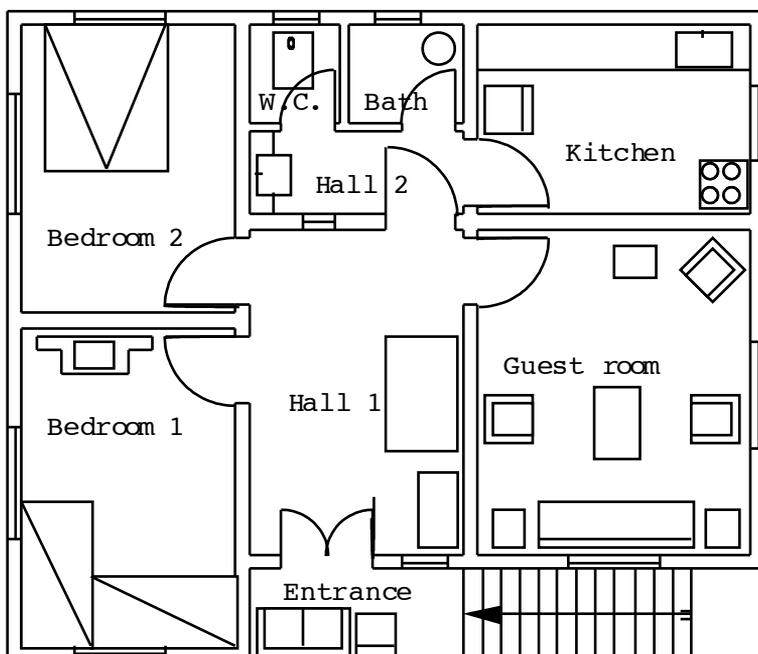


FIGURE 1 HOUSE 1 PLAN

The set of spaces in each house was determined according to the definitions given above and has been formed as a list. Rooms are the most commonly encountered spaces. However, in cases where rooms are L shaped, the problem of whether to consider to room as one or two spaces arises. In such cases, the criterion used has been whether it is possible to perceive the room as one space from various points in the room.

The activities that take place in a house generally depend on the inhabitants, their number, occupation, income, and personal tastes, as well as customs, culture and the existence of children. The activities that are generally found in all houses are given in Table 1 along with the action systems that they consist of. In addition, the activities of

cleaning, tidying up and decoration were observed in all houses without exception. As these activities take place in all spaces, they have been excluded from this analysis.

TABLE 1 ACTIVITIES OBSERVED IN ALL HOUSES AND ASSOCIATED ACTION SYSTEMS

Entertaining	Sitting with guests, talking, being hospitable.
Meals	Breakfast, lunch, dinner, formal dinners.
Snacks	Drinking tea, alcohol, eating sandwiches, cookies, etc., all non-meal eating and drinking.
Preparing Food	Cleaning, preparation, cooking, serving.
Dish washing	Washing dishes.
Sleeping	Sleeping.
Hygiene	Washing, excreting, brushing teeth, shaving, shower, bathing, etc.
Laundry	Washing and drying clothes.
Dressing	Changing clothes, dressing, undressing, make-up, beautifying self.
Leisure	Listening to music, radio, reading papers or books, writing letters, knitting, small talk.

The activities that were found in some, but not all, of the houses are given in Table 2 along with the action systems that they consist of.

TABLE 2 ACTIVITIES OBSERVED IN SOME HOUSES AND ASSOCIATED ACTION SYSTEMS

Studying	Reading, writing, drawing, numerical exercises, making models.
TV	Watching TV alone or in groups.
Games	Playing chess, backgammon, checkers, cards and other games.
Ironing	Ironing.
Work	Giving lessons, reading, writing, calculating, drawing.
Sewing	Sewing, fitting, altering.
Hobbies	Photography.
Baby Care	Dressing, changing diapers.

### Space - Activity Relationships

The space-activity relationships that have been observed in the houses studied are described through the use of space-activity incidence matrices, whose elements indicate the nature of two relations: the relation that is defined by the open statement "*space s provides the setting for activity a*" and the inverse relation  $s^{-1}$  defined by the open statement "*activity a takes place in space s*." In these matrices, if  $(a,s)$ , then the corresponding element is 1, else if  $(a,s)$ , then the corresponding element is 0. The space-activity incidence matrices of the example house is given in Figure 2.

					Meals	Dishwashing	Food Preparation	T.V.	Games	Ironing	Dressing	Sleeping	Hygiene	Laundry
Bedroom 1	1	1	0	1	0	0	0	1	0	1	1	1	0	0
Hall 1	1	1	1	1	1	0	0	0	1	0	0	0	0	0
Guest room	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Bedroom 2	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Entrance hl.	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Kitchen	1	0	0	0	0	1	1	0	0	0	0	0	0	0
Bathroom	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Hall 2	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Toilet	0	0	0	0	0	0	0	0	0	0	0	0	1	0

FIGURE 2 HOUSE 1 SPACE ACTIVITY INCIDENCE MATRIX

From an examination of the incidence matrices of the relation  $R$ , the following points have been observed:

1. Although spaces provide settings for activities in general, some spaces do not do so.
2. Generally, spaces provide the setting for more than one activity. The largest number of activities that a space provides the setting for was found as 8.

The findings related to the relation  $R^{-1}$  are the following:

3. Activities usually take place in more than one space. The largest number of spaces that an activity takes place in was found to be snacks.
4. Each activity takes place in at least one space.

Based on these observations, it may be concluded that neither the relation  $R$  nor the relation  $R^{-1}$  have been found to be functions. This finding may also be expressed verbally as "no functional relationship has been found between the spaces and activities in the houses observed."

On the other hand, we can claim that the relationships  $r$  and  $r^{-1}$  divide the set of spaces and activities, respectively, into equivalence classes. Let  $A_i$  be any independent subset of the activities set  $A$ , i.e.  $A_i \cap A_j = \emptyset$  for any  $i \neq j$ , and  $\bigcup A_i = A$ . Consider a relation  $r$  in the Cartesian product set  $S \times S$ , defined by the open statement "*space  $s_i$  and space  $s_j$  are related to at least one element of the same subset  $A_k$ .*"  $r \subseteq S \times S$ , and the relation  $r$  is an equivalency relation on the set  $S$ ; in other words, it divides the set  $S$  into equivalence classes  $S_i$ . If the relation  $r^{-1}$ , in the same manner, divides the set  $A$  into equivalence classes  $A_i$ , then the relations  $r$  and  $r^{-1}$  divide the sets  $S$  and  $A$ , respectively, functionally and create the equivalence classes  $S_i$  and  $A_j$ . In this study, it was observed that there is one to one correspondence between the sets  $S_i$  and  $A_j$ . For example, with the open statement given above, the set of spaces in the house shown in Figure 1 is partitioned into the following equivalence classes:

$SC_1 = \{\text{bedroom 1, hall 1, guest room, bedroom 2, entrance hall, kitchen}\}$

$SC_2 = \{\text{bathroom, hall 2, toilet}\}$

The subsets of activities that fall into one to one correspondence with these subsets are the following:

$AG_1 = \{\text{snacks, leisure, entertaining, work, meals, dishwashing, food preparation, TV, games, ironing, dressing, sleeping}\}$

$AG_2 = \{\text{hygiene, laundry}\}$

Thus, we can write the space-activity incidence matrix as

	AG1	AG2
SC1	1	0
SC2	0	1

What should be noted here is that spaces, which do not provide setting for any activity, should not be included in the set  $S$ .

Thus, we can make the following generalisation regarding space-activity relationships in houses: There is a functional relationship between space conglomerates (equivalence classes of spaces) and groups of activities (equivalence classes of activities) on a one to one correspondence basis.

### Space - Activity Structure

The structure of the space-activity relationships in the houses has been analysed using the approach proposed by Atkin (1974a; 1974b). This approach handles structure through the notion of a simplicial complex defined by a relationship between two sets.

The concepts of geometric representation, connectivity, structure vector and eccentricity are important aspects of this approach.

Consider the relation  $S$  defined by the open statement "*space s provides the setting for activity a.*" We call the range of this relationship the vertex set of the domain. Accordingly, space may thus be seen as a relationship connecting the vertices (activities) to each other.

A subset of  $(p+1)$  activities forms a  $p$ -simplex, denoted by  $\sigma_p$ , if there exists at least one space which is related to each of them.  $p$  is the size of the simplex. Such a space acts as a connection between the vertices of the  $p$ -simplex. In other words, a space is a  $p$ -simplex of  $(p+1)$  activities; it is a connection between these  $(p+1)$  activities. Any  $p$ -simplex is a set in the form of a list of its vertices and any subset of this set is known as a face of the  $p$ -simplex.

Using this definition observing the associated incidence matrix for the house in Figure 2, we may write the spaces in the house as the following simplices:

- 6 = bedroom 1 = snacks, leisure, study, TV, ironing, dressing, sleeping
- 5 = hall 1 = snacks, leisure, entertaining, study, meals, games
- 1 = guest room = snacks, entertaining
- 1 = bedroom 2 = dressing, sleeping
- 0 = entrance hall = leisure
- 2 = kitchen = snacks, dish washing, food preparation
- 1 = bathroom = hygiene, laundry
- 0 = toilet = hygiene
- 0 = hall 2 = hygiene

It can be seen from this list how spaces can be thought of simplices whose vertices are activities.

The simplicial complex  $K_S(A)$  associated with the relation  $S$  is the set of all simplices formed in this manner. Thus, the set of the simplices listed above is the simplicial complex associated with the relation  $S$  in the house shown in Figure 1. This complex is a mathematical construct that can be used in analysing how the simplices (spaces) are connected to the activities (vertices) and in understanding the continuity of activities among the spaces. The dimension of the simplex,  $\dim K$ , is the size of the largest simplex  $\sigma_p \in K$ . In the example above,  $\dim K = 6$  since the size of the largest simplex, bedroom 1, is 6.

### Geometric Representation of Structure

A simplicial complex can be represented by interconnected convex polyhedra in an Euclidean space  $E^H$  of suitable dimension  $H$ . Each  $\sigma_p$  is represented by a solid polyhedron with  $(p+1)$  vertices, every element of  $\sigma_p$  being represented by a vertex of the polyhedron. The complex  $K$  is represented by a collection of polyhedra connected to each other by sharing faces. Each  $\sigma_p$  requires  $p$  dimensions for its accommodation.

The required dimension  $H$  for the accommodation of the complex is  $2(\dim K) + 1$ .  $H$  is independent of the number of simplices which exist in  $K$  and the way they are connected together.

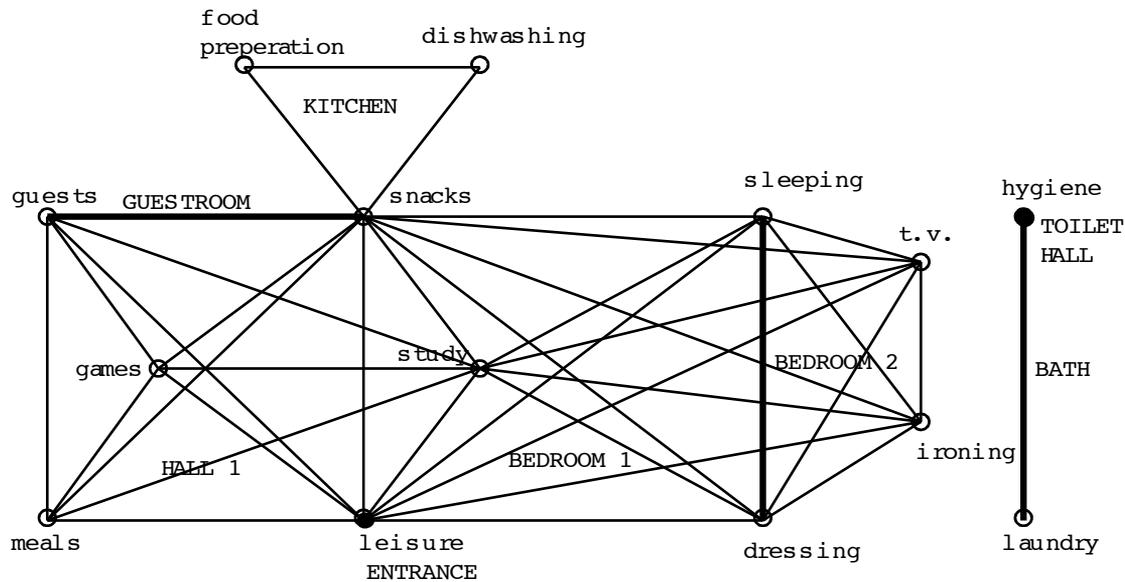


FIGURE 3 SPACE STRUCTURE ON ACTIVITIES  $K_S(A: )$  IN HOUSE 1

Thus, a geometric representation of the simplicial complex associated with the space-activity structure of the house in Figure 1 can only be drawn in a space of  $H = 2(6) + 1 = 13$  dimensions. But when we examine the incidence matrix and the simplices above, we see that the largest number of vertices (activities) which are common to two simplices (spaces) is 3 (between bedroom 1 and hall 1) and thus this common face and all others of dimension less than this can be realised in two dimensional space. If we draw the simplices sharing this common face as three dimensional polyhedra (realising, of course, that this prevent representing the real dimension of the faces of the simplices), then it is possible to draw the simplicial complex in three dimensional space. Figure 3 shows a pictorial drawing (a perspective projection from three dimensions to the paper) of this pseudo-geometric representation of the complex. In this figure, spaces appear as polyhedra whose vertices are activities. Those spaces which provide the setting for one activity only appear as a point in the construct. As the number of activities taking place in the space increase, the dimension of the polyhedron increases, with an increase only in the number of vertices after dimension 3. For example, bedroom 1, which should in reality appear as a 6 dimensional polyhedron with 7 vertices in a proper construction, appears as a 3 dimensional polyhedron with 7 vertices. Hall 1 appears as a 3 dimensional polyhedron with 6 vertices. These two spaces are those which provide the setting for most activities in the house.

The interconnection of the polyhedra (spaces) shows, through the dimension of the common faces, how many and which activities are shared by the spaces. In the example under consideration, two spaces, namely bedroom 1 and hall 1, share the planar face defined by the vertices: snacks, leisure and study. This common face shows the continuity and the number of the activities shared by the two spaces. In the same manner, bedroom 2 (the 1-simplex between sleeping and dressing) is a face of bedroom

1; this means that it provides the setting for some, but not all, of the activities that take place in bedroom 1.

We note that the structure in Figure 3 consists of two separate parts; this is a geometric expression of the fact that the set of spaces can be partitioned into equivalence classes in the form of space conglomerates as explained previously.

The space-activity structure may also be analysed from the standpoint of the inverse relation  $-1$ . In that case, the following simplices will form the conjugate simplicial complex  $K_A(S: \quad)$ :

- 3 = snacks = bedroom 1, hall 1, guest room, kitchen
- 1 = entertaining = hall 1, guest room
- 2 = leisure = bedroom 1, hall 1, entrance hall
- 1 = study = bedroom, hall 1
- 0 = meals = hall 1
- 0 = dishwashing = kitchen
- 0 = food preparation = kitchen
- 0 = TV = bedroom 1
- 0 = games = hall 1
- 0 = ironing = bedroom 1
- 1 = sleeping = bedroom 1, bedroom 2
- 1 = dressing = bedroom 1, bedroom 2
- 2 = hygiene = bathroom, hall 2, toilet
- 0 = laundry = bathroom

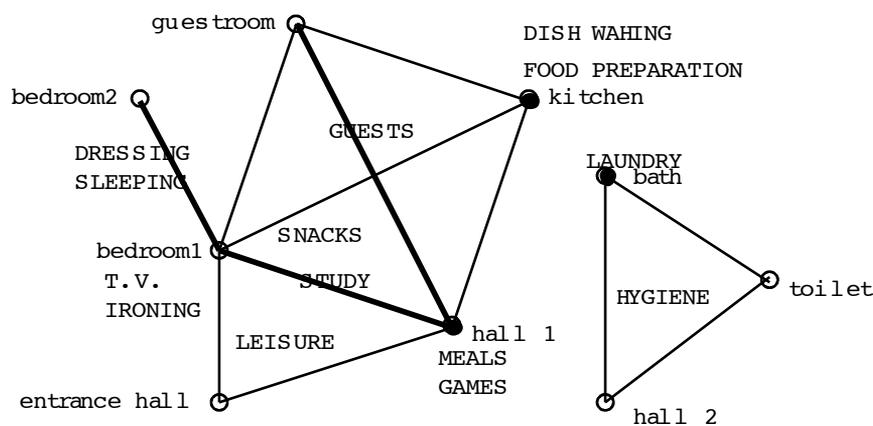


FIGURE 4 ACTIVITY STRUCTURE ON SPACES  $K_A(S: \quad)$  IN HOUSE 1

The geometric representation of the complex  $K_A(S: \quad)$  is shown in Figure 4. The dimensions of the polyhedra in this complex show how widespread a certain activity is in the house. The common faces of the simplices (activities), on the other hand, show the continuity of the interconnected activities throughout the spaces. In the house shown in Figure 1, the activity with the largest dimension (that which takes place in the most

spaces) is snacks which is a 3-simplex. The formation of the activity groups is also clearly seen in the same figure.

### Q-Connectivity

The Q-connectivity of a simplicial complex is a mathematical expression of the way the simplices of the complex are connected together. It is similar to the geometric representation in terms of the information it gives about the structure of the complex. Let us consider a complex  $K$  formed out of simplices  $\sigma_i$  and two simplices therein which we call  $\sigma_p$  and  $\sigma_r$ . If there exists a finite sequence of simplices  $\sigma_1, \sigma_2, \dots, \sigma_n$  from  $\sigma_p$  to  $\sigma_r$  such that

1.  $\sigma_1$  is a face of  $\sigma_p$ ,
2.  $\sigma_2$  is a face of  $\sigma_r$ , and
3.  $\sigma_i$  and  $\sigma_{i+1}$  for all  $i=1, 2, \dots, n-1$  have a common face,

then we say that the simplices  $\sigma_p$  and  $\sigma_r$  are connected by a chain of connection. The smallest dimension  $q$  of the common faces gives the value of the  $q$ -connectivity of this chain. According to this definition, a  $p$ -simplex is  $p$ -connected to itself by a chain of length 0.

In the geometric representation given in Figure 3, bedroom 1 is 2-connected to hall 1 by a chain of length 1, and the guest room is 0-connected to bedroom 2 by a chain of length 2. The fact that two spaces are  $q$ -connected means that they provide the setting for the same  $(q+1)$  activities. Thus, in the connection of the bedroom 1 and hall 1 above, these activities are snacks, leisure and study. This is also an expression of the activity continuity between the spaces and of that fact that one may proceed from one space to the other without changing activities. If two activities are connected by a chain of length greater than one, then passage from one to the other is only possible through a change in activity. Passage between non-connected spaces is possible only if activity groups are changed.

### Q-analysis

The relation  $\sigma_p \sim_q \sigma_r$  which is defined by the open statement "*simplex  $\sigma_p$  is  $q$ -connected to simplex  $\sigma_r$* " is an equivalence relation on the set of simplices of the complex  $K$ , which are of dimension greater than or equal to  $q$ . The equivalence classes are elements of the quotient set  $K/\sim_q$ .  $Q_q$  is the number of the  $q$ -connected components.

Q-analysis is the process of finding the numbers of the  $q$ -connected components  $Q_q$  in a complex  $K$  for all values of  $q$  from  $q = 0$  to  $q = \dim K$ . The results of the Q-analysis of the simplicial complex  $K_S(A: )$  is given below:

bedroom 1	6				
		2			
hall 1	5		0		
		1		1	
guest room	1		-		0

bedroom 2	1	-	-	0	-	-	-	-
entrance hall	0	-	-	0	-	-	-	-
kitchen	2	-	-	-	-	-	-	-
bathroom 1		-	-	-	-	-	-	-
hall 2	0	0	0	-	-	-	-	-
toilet	0	0	0	-	-	-	-	-

The elements of this symmetric matrix, which has been written in condensed form, show the value of the  $q$ -connectivity between two spaces. For example, bedroom 1 is 6-connected to itself; thus, it provides the setting for 7 activities. Furthermore, bedroom 1 is 2-connected to hall 1, 0-connected to the kitchen and not connected to the bathroom.

The values of  $Q_q$  and the equivalence classes in the quotient  $K/ q$  obtained from the matrix of  $q$ -connectivity are as follows:

- $q = 6$      $Q_6 = 1$      $6 = \{(\text{bedroom 1})\}$
- $q = 5$      $Q_5 = 2$      $5 = \{(\text{bedroom 1}), (\text{hall 1})\}$
- $q = 2$      $Q_2 = 2$      $2 = \{(\text{bedroom 1, hall 1}), (\text{kitchen})\}$
- $q = 1$      $Q_1 = 3$      $1 = \{(\text{bedroom 1, hall 1, guest room, bedroom 2}),$   
(kitchen), (bathroom)\}
- $q = 0$      $Q_0 = 2$      $0 = \{(\text{bedroom 1, hall 1, guest room, bedroom 2,}$   
kitchen, entrance hall), (bathroom, hall 2, toilet)\}

### Structure Vector

The integers  $Q_q$  of a complex  $K$ , with  $\dim K = N$ , define a vector  $Q$ , called the structure vector,  $Q = (Q_N, Q_{N-1}, \dots, Q_q, \dots, Q_1, Q_0)$ . The elements of this vector show the number of independent pieces that the structure consists of at the level  $q$ . The  $Q$  vector for the example house is  $Q = (1, 2, 2, 2, 2, 3, 2)$ . Accordingly, the structure  $K_S(A: )$  consists of two independent equivalence classes at the level of 0-connectivity as described above. In general, a structure vector comprising elements which are small indicates a structure consisting of strongly connected, in other words unspecialized spaces, whereas one comprising large numbers points to a structure consisting of fragmented, specialised space conglomerates.

In a manner similar to the  $Q$ -analysis if  $K_S(A: )$  expressing the interconnectivity of the spaces in terms of the activities, the  $Q$ -analysis of  $K_A(S: )$  will show the continuity of the activities in terms of the spaces they take place in. The results of this analysis for the example house are as follows:



3. In houses where there are two equivalence classes at the  $q = 0$  level, the spaces in the third space conglomerate connect strongly to that conglomerate of the former two which is the highest  $q$ -connected.
4. The kitchen appears as the most specialised (eccentric) space in houses. At the  $q = 1$  or the  $q = 0$  levels, it forms an equivalence class by itself.
5. The complex of spaces interconnected through activities,  $K_S(A: )$ , is a structure which can be used to analyse whether activities can take place in a specific space.

Regarding the structure  $K_A(S: )$  associated with the relation of activities in terms of spaces, the following findings can be stated:

6. The activity observed to spread throughout most spaces in the houses is snacks. This activity is connected by the spaces kitchen, living room, study, balcony, etc., which are often seen to be in the same space conglomerate.
7. The complex of activities interconnected through spaces,  $K_A(S: )$ , is a structure which can be used to analyse the spread or separation of activities through spaces, and the number of spaces in which activities can take place.

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