

# ADAPTIVE ENVIRONMENTS: *SPATIAL* *ADAPTATION BY RECONFIGURATION*

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## **Abstract**

Space Crunch” is a daily struggle in the life of majority of Urban Dwellers, more so for growing families to which they either respond with unique design solutions or compromise. Internal non load bearing walls occupying valuable floor space is one of the reasons contributing to this “Space Crunch”. Thereby necessitating a study to explore transformations on the

Wall plane. This paper is a study of reconfigurable systems both on the wall as well as roof plane leading to an apt design solution for Reconfigurable, Internal Modular space dividers in Tensile Fabric. The paper would finally conclude with a conceptual design solution answering the “space crunch “ issue enhancing functional efficiency of residential dwelling units with changing occupants.

## **Keywords:**

Adaptive Environments, Spatial Adaptation, Reconfiguration

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## Space Crunch : A by product of rising urbanisation

Migrating population is on the rise as cities offer lucrative employment opportunities. But work places go hand in hand with corresponding dwelling units, to house this growing populace. Land is limited and families still has the potential to grow. Predictably needs also grow and households need more space. This has been going on right from the time of Industrial Revolution and humans have always found a solution because they possess this incredible power to "Adapt"to changing situations, one of which is through "Spatial Transformation".

### Concept of Spatial Transformation

"Spatial Transformation" in this context is defined as any

- ALTERATION
- ADDITION
- EXTENSION
- MODIFICATION

Of Residential Interior Space Usage

It has been identified as an integral part of Inhabitation. In the context of self built houses in developing countries [1], as well as homes all over the world occupied by the Urban populace ,studies show that there is an abundance of transformation incidents. [2].

Transformation in Interior walls is defined as Partition Level [PL] transformation, by the author T.H. Khan in his book Living with Transformation. Permanent construction works is involved as the Internal non load bearing walls are made of Bricks which is a rigid material.

### Categories of Partition level Transformation

1. **EXPANSION:**The size of one unit is increased by devouring some space from

adjacent units on the same floor.For eg : as families grow, a larger bedroom is required and a smaller dining space is acceptable as a compensation[Fig 1]

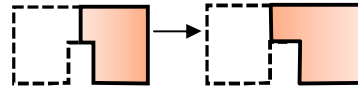


Fig 1 : Transformation by expansion

2. **REDUCTION** : The size of one unit is reduced usually due to change of usage of part of any area into non residential activities.[2] For eg : the reduced part becoming office or storage space.(Fig 2)

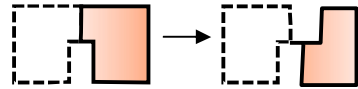


Fig 2 : Transformation by reduction

3. **SUBDIVISION** :It involves constructing or demolishing partition walls , or simply closing a door or two so that parallel private functions can be carried out in

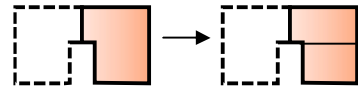
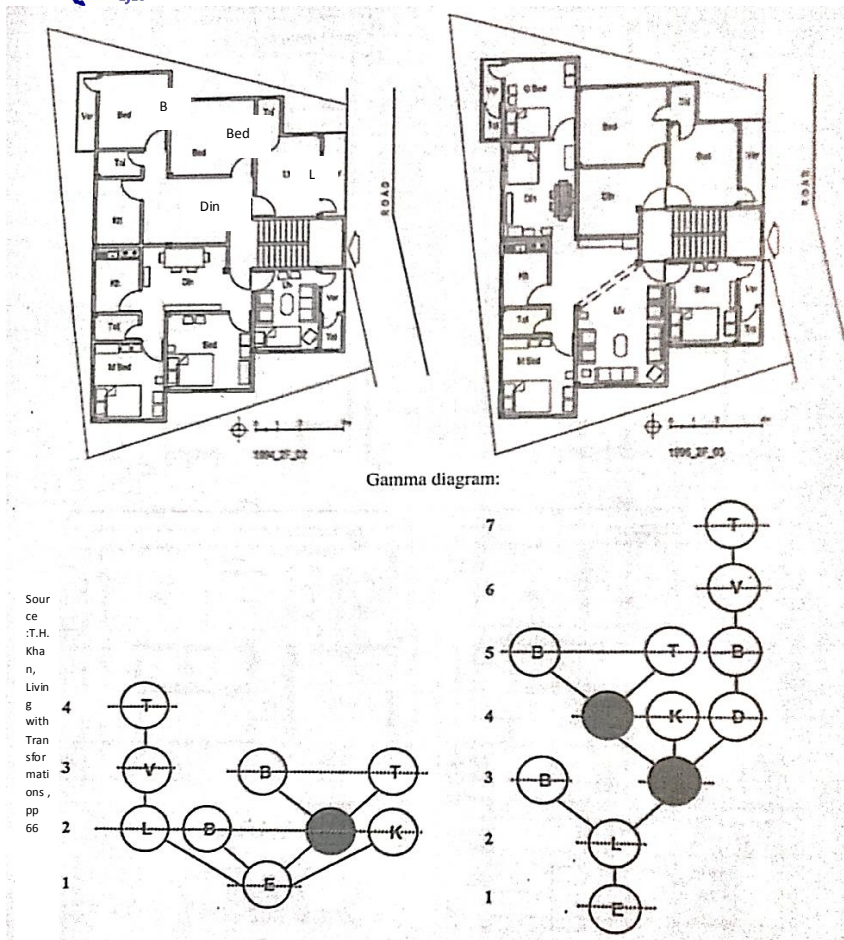


Fig 3 : Transformation by subdivision

these subdivided areas. [2] (Fig 3)

These categories of transformation incidents are a common occurrence in small dwellings in urban areas causing "Space Crunch" due to rigid internal non load bearing walls occupying valuable floor space .



Internal subdivisions causes increase in circulation space, thereby resulting in more wastage of space. (Fig 3)

internal circulation is reconfigured by shifting the position of few non load bearing walls resulting in transformation by subdivision.

As families grow, sometimes adjacent flats are purchased and merged into one and the

Carpet area = 900 sq. ft [Area occupied]  
 Loading factor = 25% [125]  
 Built up area = Carpet area +  
 Bed  
 Loading factor B  
 D = 1125 sq.ft.

Therefore, **Carpet Area = 80 % of Built up Area**

Balance 20% is profit for the builders.

Out of the above mentioned 80%, rigid space divisions in the form of internal walls, further reduces maximum space utilization.

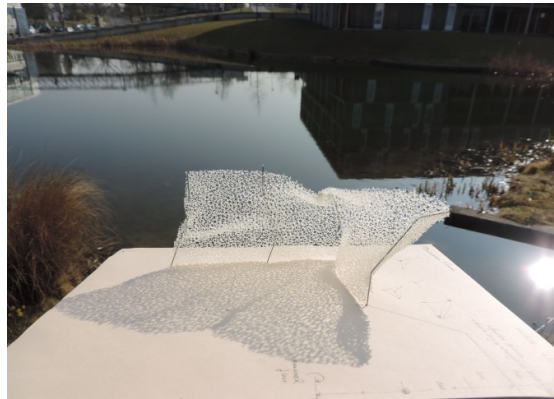
**Actual space utilized = 70% of Built up Area**

In such a scenario, Reconfigurable Modules of Tensile fabrics can greatly reduce space wastage by an astonishing **20%**, as there is **reduction in area covered by fixed walls, & the reconfigurable nature of tensile modules makes multiple internal wall configurations easy, thereby achieving optimum space utilization.**

### Reconfigurability on the wall and roof plane : Built examples

This study was undertaken to understand the design characteristics of reconfigurable modules. Even though majority of the featured projects show reconfigurability on the roof plane, their analysis led to the kinematic development of the conceptual design of Lightweight modular walls.

**1Project : ROOF OVER SWIMMING POOL** in Unterluss, Germany.



### References

- Thereby it is seen that there is scope for further research in the field of Lightweight Modules, Walls, Rooms, Flexible Internal Spaces, Enhancing Functional Efficiency of Residential Buildings, *Architectural Design*, 16, 2008, 10-11.
1. T.H.Khan, (2014) Living with Transformation. *Springer Briefs in Geography*
  2. Brian Foster & Marijke Mollaert. The real estate prices in metro cities are as follows. (2004). *European Design Guide for Tensile Surface Structures*, 56, 57, 115
- The following table shows that residential spaces are becoming more and more unaffordable for the middle class sector (Table 1).

City	Rate per Square Feet
Mumbai	17,000 Rs.
Bangalore	8,000 Rs.
Delhi	20,000 Rs.
Kolkata	7,500 Rs.

A general trend in India, shows that home

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Photographs: Courtesy the author.



Fig 4 : Internal View of Swimming pool showing double layered membrane roof[barrel form].(3)

COMPLETE RECONFIGURATION

Architectural Firm : L. Stromeyer & Co.  
Year : 1972  
Reconfigurability Analysis : Double Layered membrane = **good design for reconfigurable modules**  
From the point of view of reconfiguration, if a module consists of 2 layers of fabric with an intermediate air space of between of minimum 3 cm. The intermediate pressure in the double layered skin can be used to control the foldable structure, which gives it stability in a reconfigured position. This concept is in function, but in the form of an external envelope reconfiguration.

Fig 24: Model Experimentation showing complete reconfiguration swimming pool at Unterluss, Germany

Conceptual Design Solution



Fig 5: Closed to open position showing folding action of the umbrellas[clockwise from top left]

2Project: CANOPIES FOR SHADING COURTYARD OF PROPHETS MOSQUE IN Medina

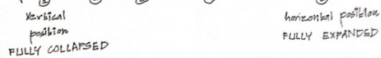
This design would be a lightweight modular, light transmitting alternative to conventional architectural forms like Brick/wooden partition walls. It is highly advantageous in Reconfigurability Analysis. Modules with an inherent flexible geometry, Utilizing folding action via "Spatial Transformation".

The project described above [Fig 5] is of 17 X 17 grid pattern for ENRASHO in Riyadh. It is a courtyard of prophets mosque in Medina, Saudi Arabia. Design of this courtyard is based on folding permanent construction marks. Design of this courtyard is based on states of deployment, fully collapsed permanently, thereby saving on circulation space. (Fig 25) process of deployment the cantilevering arms of an umbrella like structure that from a vertical to a horizontal position with large open structure in the visible floor space thereby answering the "Process of this courtyard" occupies a considerable volume of unobstructed space near the central space. However as this concept is proposed to be applicable in home interiors, the process would have lightweight modular walls defining flexible internal spaces is indeed a smart solution catering to the changing needs of the urban growing families of India & simultaneously allowing maximum utilization of space, thus enhancing functional efficiency of residential

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used as internal space dividers  
in Residential Interiors

Derived from comparative analysis of reconfiguration projects.

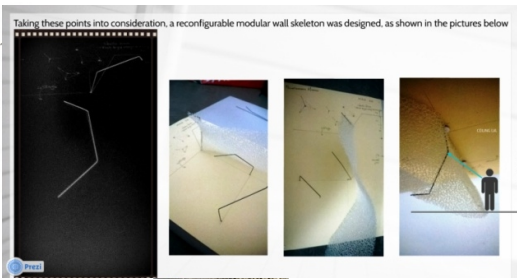


Reconfiguration Principle	reconfiguration[1-5] zone formation.
Design	<ul style="list-style-type: none"> <li>Skeletal frame is more advantageous in the context of this design, described as a point-line system of ceiling channel.</li> <li>Double Layered perforated canopy over free zone on floor defining each module</li> </ul>

Similarly in the context of this research, the mechanism implies a 100% thereby allowing a complete free zone on the floor level, attached at the roof level.

Fig 20 :Foldable module design fixed at the Ceiling.

Scale	Easy handling by home occupants
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Material	<ul style="list-style-type: none"> <li>Adaptability to indigenous climate</li> <li>Use of Freeform surfaces</li> <li>Glass based fabrics with high fire rating.</li> <li>Prevents tearing.</li> </ul>
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Architect : Jean Nouvel.  
Year : 1988

Conceptual Design Solution  
Adhering to these Specifications

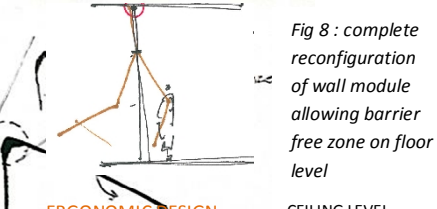
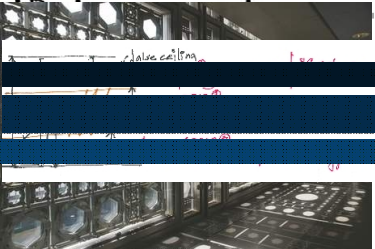


Fig 8 : complete reconfiguration of wall module allowing barrier free zone on floor level

**ERGONOMIC DESIGN**  
Considering the human height and scale of the room of a general apartment [2.7 M] in Reconfigurable Analysis the overall vertical height of the user can be divided into 3 zones. [Fig 21] below  
Transformable facades have been used in the past as part of environmental strategies for day-lighting control within buildings. An example of a transformable facade (Fig 23) at the Pompidou Centre in Paris, France, was not the sole intention of the space frame. The World Centre of Gravity in Paris, France, to support the fabric enclosure consists of 27,000 motor-operated aluminium retractable rings divided into 113 panels. Each panel is operated individually with equipment of a touch sensitive mechanism,



similar to the iris-type diaphragm of a Project (Fig 9) Conclusion: Textiles and non-woven materials in the over outdoor designs will be kinetic devices that can be flexible lighting and shade of the building, according to the weather and seasonal conditions. This is a very high-tech and beautifully engineered solution for a transformable facade. Unfortunately, due to high maintenance and operational costs the rings no longer work. Commonly, the iris-type diaphragm used within photographic cameras consists of number of very thin metal blades mounted on a base plate and

1. ROOF OVER Barrel Form

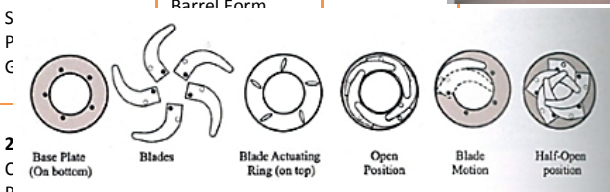


Fig 10: Parts of the Iris Diaphragm (3)

covered with a blade actuating ring that has a series of welded pieces (Fig 10). By rotating this ring the welded pieces push or pull the blades and the size of the openings can be varied. (3)

4. THE SWIVEL DIAPHRAGM With this system the blades overlap each other during the deployment; as a result they are forced to operate on a sloped angle. The slope of the blades increases as they approach the closed position. This is more evident when the width of the blade is greater. Such conditions restrict the range of designs possible with this system.

### Reconfigurability on the wall and roof plane : Conceptual

#### 5. QI ZHONG TENNIS CENTER

Researchers have always looked for a simpler and most effective solution with regard to Shanghai, China. Filling this gap and have come up with innovative designs, some of which are described below

#### 4 Project : THE SWIVEL DIAPHRAGM

Fig 19: PROPOSED DESIGN of QI Zong Tennis

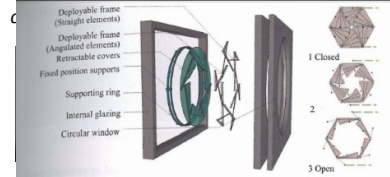


Figure 11. Potential transformable facade, configuration of the module.



Fig 11: Potential transformable facade utilizing a simpler swivel diaphragm CONCEPTUAL DESIGN (5)

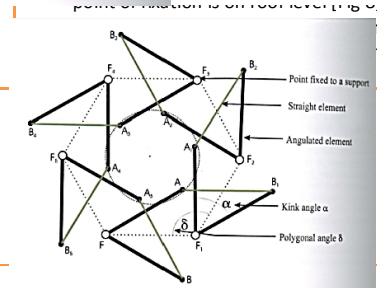


Figure 1. Hexagonal swivel diaphragm, main components.

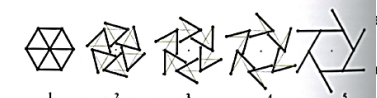


Fig 12: Hexagonal swivel diaphragm and its process of deployment (5)

frame and PTFE Membrane cushion as a material of choice is an improvement to the current design (Fig 19 & 16). The swivel Diaphragm is a retractable structure and is at a conceptual design stage. Non-woven textiles like Ecombrane and are an apt choice for kinetic devices which reconfigure on a regular basis.

Specifications for a Reconfigurability Analysis: Modules with an inherent flexible geometry. Utilizing

**Swiveling action on Polygonal** it's current **conformation** is its geometry.

It is constituted by a concentric series of angles and straight elements. **Conclusion of Project 4:** Swiveling action can be used for reconfiguring the wall modules together through elementary pivot joints. However a new geometry is needed to be applicable to the research field in which all the elements expand and contract simultaneously from or towards the centre of the structure. i.e. Residential Interior **Project 5:** Qi Zhong Tennis Center Shanghai, China

Therefore any force applied to a single component spreads through the rest of the structure. [Fig 12]. Architectural Firm :Mitsuru Senda in cooperation with SIADR (Shanghai Institute of Architectural Design & Research)

The ingenuity of this design is the link and the flexibility of its individual components. This allows it to be **operable in one plane**, therefore space/activities on either side of the plane is **not disrupted** [Fig 13].

**Reconfigurability Analysis :Retractable Roofs**  
**The reason why textiles are most suited for kinetic /reconfigurable devices**

**Fig 13: Design Advantage : Movement in one plane**  
In recent decades retractable roofs have become commonly used for venues where variety of outdoor and indoor activities can be performed.

The Qi Zhong Tennis Center in Shanghai is the only known built project that uses a retractable ring roof structure.

This is the largest tennis facility in Asia, with a seating capacity for 15,000 people. It has a 223m diameter retractable ring roof which

Structures operable on the retractable ring mechanism due to the swiveling action have



**Fig 16: BUILT DESIGN of Qi Zhong Tennis centre, Shanghai** Petal form of retractable roof(5)

be applied in areas where specialized technology is not available. From the point of view of this area of research, this design concept has a potential to be applicable as

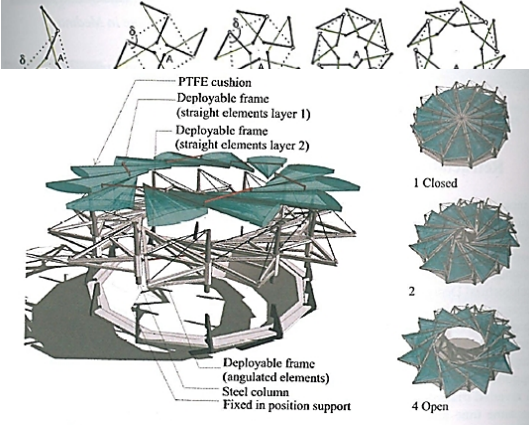
reconfigurable light pipes, pipes of low sizes (3 families).

**Disadvantage** shape truss turns around on one. However at close range and in bright light the point of being appropriate is to be eliminated. The vertical spaces between the truss members are not ideal for the use of the ceiling. On the other hand, the polygon has a tendency to expand in all directions. The pedestrian leaving gaps in the position (Fig 16) / apartment house has a fixed vertical boundary that of the proposed ceiling, as shown in the diagram below.

**Fig 17 & 18 :PROPOSED DESIGN of Qi Zhong Tennis centre, Shanghai and its opening detail(5)**



conditions, therefore disadvantages will be eliminated in order to make the design more energy efficient and at the same time eliminating the gaps.



This creates a pathway for further research and experimentations which might give