DESIGN OF FURNITURE SYSTEMS FOR AFFORDABLE HOUSING - FITTING MORE IN VOLUME

INDUSTRIAL DESIGN PROJECT II

IDP602

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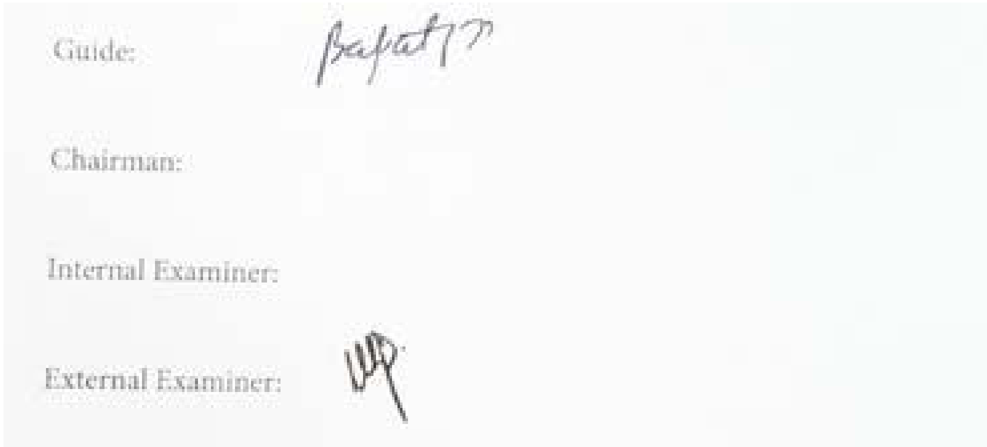
Approval sheet

The project titled as "Design of Furniture Systems for Affordable Housing-Fitting more in Volume" by Vishal Bhusan Jha is approved in partial fulfilment of the requirement for the degree of 'Master of Design' in Industrial Design.


Guide:

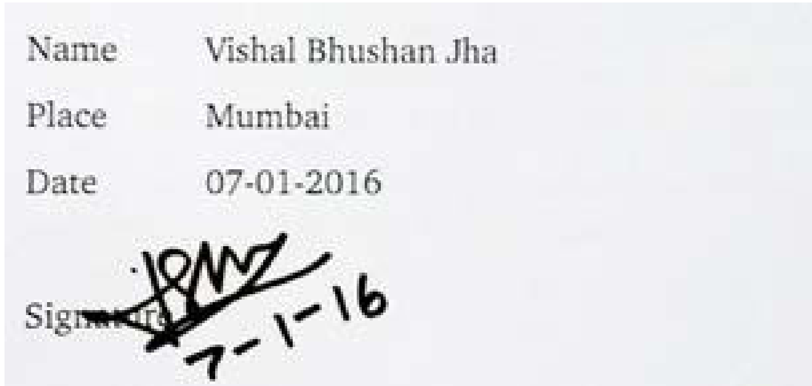
Chairman:

Internal Examiner:

External Examiner:

Declaration

I hereby declare that this written submission represents my idea in my own words and where others' ideas have been included; it has been adequately cited and referenced with the original source. I declare that I have adhered to all principles of academic honesty and integrity and have not fabricated or falsified any data/idea/facts/sources in my submission. I understand that any violation of the above entitles the institute to take disciplinary action against me to which I shall be answerable to.



Name Vishal Bhushan Jha

Place Mumbai

Date 07-01-2016

Signature

7-1-16

Acknowledgement

I take this opportunity to thank the entire Industrial Design department for the success of the project.

I express our deepest gratitude to our guide Prof. Uday Athavankar and Prof.Vijay Bapat for their guidance in this project. The project has been a great learning experience till now.

I am grateful to my seniors(Manu Ravi, Gautam Verma and Anulal) who had worked on the project before me. Foundational bricks of their work has helped me immensely in understanding the current scenario well and provided the required information. I would Thanks Mr. Vivek and Ranjan for helping me in prototyping.

Last but not the least, i thank our batchmates who have contributed their insights to this project.

Abstract

The title of this project is Furniture system design for affordable volumetric housing. There is a huge shortage of housing in urban areas mainly because of shortage of land and very high prices of the land existing. Hence there are slums that are developing in cities to accommodate the large population of immigrants coming continuously to cities.

To overcome the housing shortage and provide good living condition in lesser area, Affordable housing-Fitting more into volume was a project carried out from July 2014-nov 2014 by 3 IDC students: Manu Revi, Gautham Varma and Anulal. The project dealt with creation of spaces by utilising volume and going vertical and giving exact head room as required. Based on these studies, the minimum space required for a family of 6 members was calculated and different layouts were made for the same.

A permanent mezzanine structure in a small house might not qualify with the building bylaws of many places. Thus, if the furnitures make the mezzanine floor, it will not be considered an additional floor thus qualifying stricter bylaws.

For the current project of Furniture System design for volumetric housing, the basic concepts of spaces arranged in volumes, listing of heights and accommodating 6 people is taken from previous project. On the basis of the previous project and current study of slums and sheet metal working, new layouts were made keeping in mind flexibility in layout and optimal utilization of spaces. The layouts created allowed various possibilities of arrangements with the same components. Then the furniture

are detailed with 3 approaches: Wall fixed furniture, Floor standing furniture and central core supporting all furniture. Throughout the project, the most important factor that was followed was keeping in mind if it can be DIY, Incremental, Economical and space saving. At many places the weight of components and materials also was considered as it was DIY assembly and need to be light to be easily handleable.

Contents

Million Plus Cities	Proportion of Slum HHs to Total Urban HHs (%)
Greater Mumbai (M Corp.)	41.3
Kolkata (M Corp.)	29.6
Chennai (M Corp.)	28.5
Delhi Municipal Corp (U)	14.6
BBMP (M Corp.)	8.5

Source: Census 2011

Fig: 1 Percentage of slum households in metro cities

Fig: 2 This social housing built in Dharavi under the Slum Rehabilitation. as seen at www.airoots.org/2008/05/junglist-city/

1. Introduction

Growth of city comes hand in hand with growth of slums in the present day scenario in India. People migrate to cities from villages in large volumes in prospects of better opportunities, health, education and other comforts. But in reality most of these people are extremely poor and cant afford any of these when they arrive to the city immediately. Hence they end up living in the unorganised settlements like slums or squatters for the time being (Ref. fig 1). When they cant upgrade their housing conditions and end up living in the slums forever lies the issue.
The people migrated previously are living in the squatters but there is still continuous migration of new people from villages to cities. This often results in creation of large slums which are more difficult to relocate/develop than smaller ones. Mumbai has many examples of such slums all over.

Many of Indian metropolises have no quality space for new people in, and are growing in area towards satellite towns and suburbs. These new developments are not planned properly hence new immigrants to the city are causing issues with the city development. But on the other hand they are very important as they provide workforce and cheap labour to city population. For this it's important for us to provide proper planned development to these people and accommodate them in good liveable conditions. The Project "affordable housing – Fitting more into Volume" aimed at providing solutions to the housing problems in urban areas and providing good housing conditions to the dwellers.
As a continuation of that project, the current project of Furniture system design for affordable housing deals with design of furniture system for the housing solution to utilise the volume of the house. Many times the Slum redevelopment housing units(Ref. fig. 2) are not designed keeping in consideration better living spaces and

Fig: 3a Residents of Mumbai's Dharavi slum as seen at http://www.telegraph.co.uk/news

Fig: 3b Aerial view of Dharavi, Mumbai as seen at www.airoots.org

better quality living. This Furniture system will be designed taking into consideration the needs of slum households giving them flexibility in layouts and allowing them to install the system in phases. Many times, the people coming to city from villages are economically very poor hence can't afford to buy the components all together. To overcome this situation Incremental growth of housing is important such that the house grows whenever required.

Slums:

Slums usually develop at city centre as cheap labour is required in those areas, Prospects of employment is really high and the labour force doesn't want to travel a lot to come to the workplace. Usually one slum house accommodates 5+ people. A person with place in city often calls their relatives from villages to live with them.
There is usually a single room in a slum house host. There is very little to no privacy. The walls are structurally unstable and structure weak. House is usually cramped with several storages. The house is often dark all day with no natural lighting. All the areas in the household is multiuse space and most of them become a separate function area at that point.
The people living in the slums can be categorised into four types: Transients, Settlers, Hedonists and Risers. The people who just migrated to the city and are doing temporary jobs while in search of a good job, come under transient category. Settlers are those who have found a reasonable permanent job that pays enough to sustain their livelihood. They would not spend much on things or artefacts that are permanent, for example, a concrete staircase or permanent tile flooring. Hedonists, on the other hand, would spend money on comfort. They would be generally bachelors who have low-end jobs. Risers are people with education and tend to climb up the social ladder as well as in employment. (Based on earlier studies by IDC over a period of 3 years, though yet to be published).

Fig: 4a Inside view of full scale model of Affordable Housing - fitting more in volume

Fig: 4b Inside view of full scale model of Affordable Housing - fitting more in volume

About project 'Affordable housing - fitting more into volume'

This project was done in the duration of July - Dec 2014 by Mr. Anulal, Mr. Gautam Varma and Mr. Manu Revi of IDC 2013-15 batch. The project Mainly looked at utilizing volume along with area and going vertical for space saving and affordability.

- Interesting living spaces with sufficient head room created by arranging spaces intelligently.
- Could accommodate a family of 6 people (couple + 2 kids + parents)

Fig. 4a and 4b show some interior views of the project. Further details about this project could be found in the Annexture 1 at tne end of this report.

Why furniture approach?

Creating two levels in a house along the height is usually done by permanent structures such as casting, deck slabs or creating platforms. When there is a permanent structure coming in as mezzanine slab, its often considered as an extra floor at many places according to their building bylaws.
If the mezzanine level deck/platform is supported by furniture systems or gets support from the ground without getting fixed with the wall anywhere (like a table) then it gets considered as a furniture not a slab which adds another floor to the house.
There are various advantages of taking furniture approach for affordable housing - furniture system design project. Some are:

- Can be portable, moved to places.
- the components are independent of each other and designed as per phases of development hence can be bought in phases when the person can afford it.
- adds upper level to house without compromising on building bylaws.

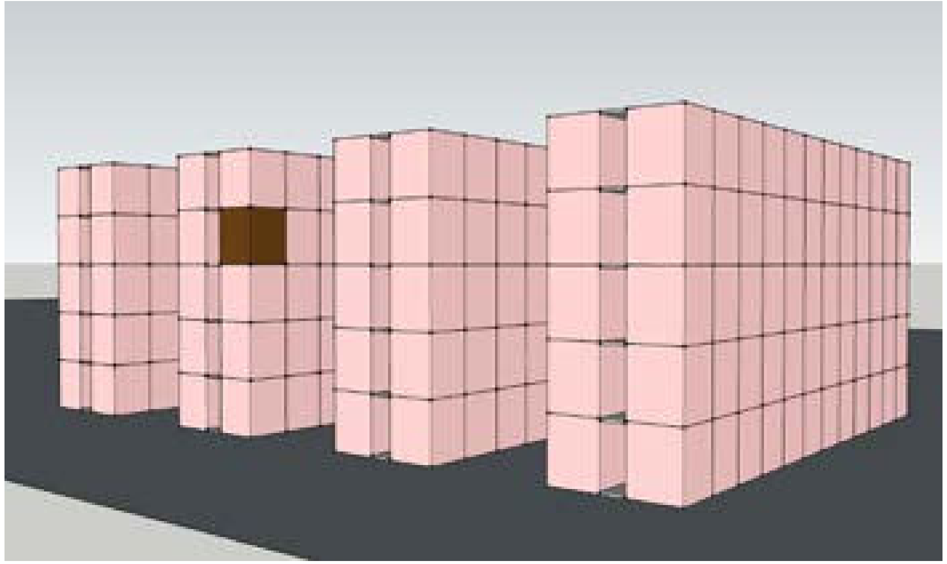


Fig: 5 Assumed clustering of the houses with one unit highlighted

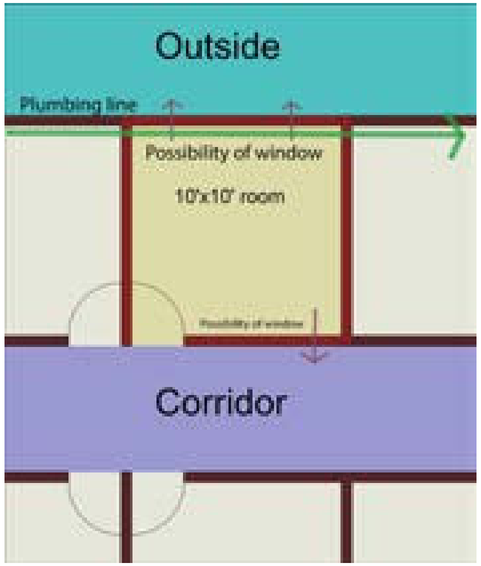


Fig: 6 the provisions available in one particular unit

Assumptions

- The space to be designed is already available as multistorey building having modules of size 10'x10'x12.5'.
- The wall strength is unknown. The rooms have one exterior wall which contains windows and all the plumbing connections and one interior wall which opens in corridor with window and door.
- Every building has a passage of six feet (6') between the two opposite facing modules.
- The simple unit with all basic provisions are mentioned in Fig 6. The figure shows a particular unit of size 10'x10'x12.5'.

Fig: 7 Basic plans of all houses studied

Data Collection

Slum visit and analysis

I visited 2 slums in Mumbai for understanding the arrangement of a slum dwelling, their interior arrangements and lifestyle. The first slum I visited was Phule Nagar near Kanjurmaarg. I visited 4 houses there, each slightly different from other.

House No. 1:
Family of 5 lives there. Its one of the rare houses with a Bed in it.

House No 2:
A couple and the husbands 3 brother live there. Very simple house with no bed. Cooking is at floor level.

House no. 3:
One big house divided into 2 small rooms after partition among brothers. There are 2 kitchens, 2 bathrooms and everything else.

House no 4:
The house accomodates family of just 3. The house is neatly arranged with a bed, partitioned kitchen and table-chairs for sitting.

Post visit analysis of the house was done to find out the major floor standing, wall mounted and ceiling hung items inside the house. The details are given in the table 1. This analysis helps in easily finding out the components required inside a slum house.
Post analysis, I wrote the observations and comparisons in a table form. Table 2 includes the observations, surprise factors, descriptions and possible suggestions/learnings.

Case study (House layout comparision)

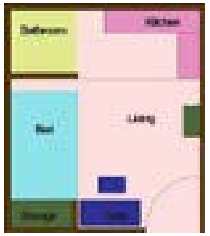
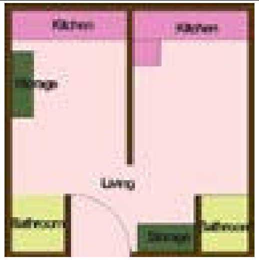
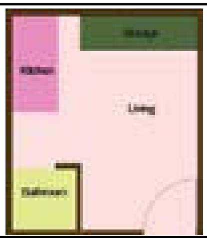
Sr. No	Layout	Picture	Floor standing Elements	Wall Hanging elements	Ceiling suspended elements
1			Bed Sewing Table Stool water barrel bucket kitchen cabinet and slab Gas cylinder small table with water vessels	TV shelf Puja area chappal storage shelf Loft Bathroom shelf Kitchen shelf Utensils storage Shelf over door Tube light Wires for hanging clothes	Fan Loft support
2			Closet Stool water barrel bucket kitchen cabinet and slab Chair Gas cylinder Metal storage box	Wires for hanging clothes TV shelf Puja area Loft Bathroom shelf Kitchen shelf Utensils storage Tube light	Fan Loft support Storage
3			Storage cabinet Kitchen cabinet Gas cylinder Bucket Small table with Matal suitcase water barrel	Wires for hanging clothes Puja area Loft Bathroom shelf Utensils storage Tube light Shoes Dressing area	Fan Loft support
4			Bed Table Kitchen slab and shelves Water barrel Gas cylinder hidden Bucket Storage cabinet Small hight table Plastic chairs	TV shelf Puja area chappal storage shelf Loft Bathroom shelf Utensils storage Tube light Wires for hanging clothes	Fan Loft support

Table 1 Case study : Houses furnitures comparison. we can see that only two houses have beds. Beds occupy a large portion of the house where ever there. But also it provides opportunity to do under-bed storage. Another observation is the number of wall mounted elements which is much higher than floor standing and ceiling suspended furnitures.

Fig: 8a Photographs of interior of slum houses

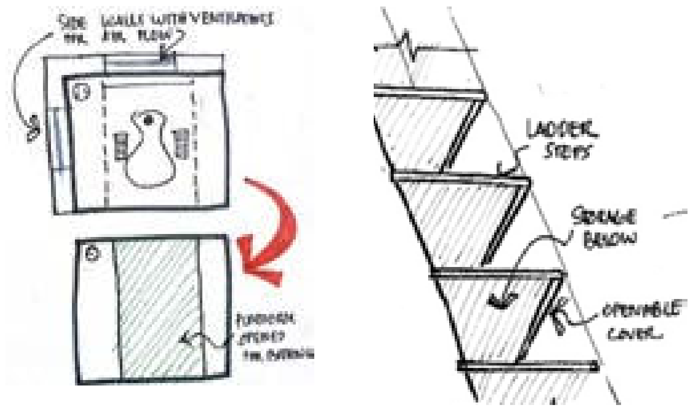


Fig: 8b Suggestion for toilet and Below ladder storage

Observations from slum visit

Adaptive usage of space

Storage happens in loft and below furniture. Boxes to store garments in each house .Very few closed cupboards are there and all shelf storages are open.
Suggestions: Loft space advisable in house. If headroom constrains - smaller loft with 2 layers of shelf.

Bathroom in each house

Public toilet mostly used for excretion usage, reason for this are: space constrains, Privacy/odour issue and Plumbing. Bathroom is open from one side with curtains. Sizes of bathrooms bigger compared to house size.
Suggestions: Toilets which can be covered and used as bathroom advised. For odour, corner space with ventilator on 2 walls

Shelves common throughout the house

Just at the lintel level at entrance, large storage shelf. There are several other storage shelves all around the house.
Suggestions: Below ladder space could be effectively used as shelf. Also hanging open able storage below deck wherever headroom is not a constraint is possible

200lts water Barrel in almost every house

More water is present at house than expected. The blue water barrels are used for storing water that is used in cooking, bathing and slight washing. Small pipes carry water from main line to home.
Suggestions: Special water tank of cuboidal geometry can be more

Fig: 9 Interior of slum houses showing compact kitchen, Bed in house and bathing space. Also suggestion for multipurpose kitchen sketched.

space saving. Water tank advisable to be put above toilets & Kitchen.

Compact kitchens with cooking slabs

Most of the kitchens are really compact and organised with ample storage above and below the slabs. All the vessels, Groceries and gas cylinder are housed in the specific place in their own “Modular Kitchen”
Suggestions: heavy duty kitchen slab is must. Washing and drying area can be combined and overlapping. Flexibility/options in standing cooking and sitting cooking to be given

Area below ladder used as bathing space

Barely straight standing space is used for bathing. The position is really uncomfortable.
Suggestion: Bathing space needs good headroom so slanted wall is not advised. Instead area below ladder is good alternative to loft storage.

Bed not important

Most of houses do not have bed as Sleeping on floor is more accommodating and comfortable. Bed occupies maximum spaces in the house. Still few people had bed and it covered almost 40% of house area. Bed takes up more space and most houses have 4+ number of people living.
Suggestion: Foldable or collapsible beds can be good options as that will allow usage of the free space in day time and converting it into bed in night time.

Fig: 10a Interior of slum houses showing wall recess as shoe rack and drying ropes

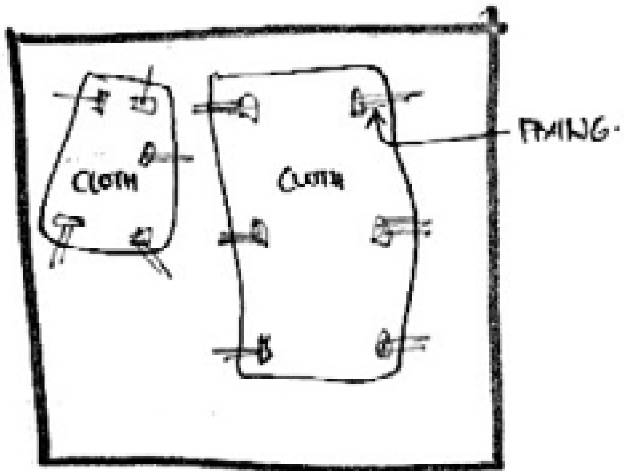


Fig: 10b proposal of drying clothes on ceiling

Small recess in wall used in storing

Each and every recess in wall is utilized. Even small ledge created while wall changing of wall thickness used as cosmetic and shoe storage
Suggestions: Joints in members/Assembly details of furniture can become interesting micro storages

Ropes for drying clothes

They don't possess many clothes so main drying space required is for bed sheets and saris. Surprisingly there are very less number of drying ropes in most of the households.
Suggestion: Saris and sheets drying space to be designed specially. Roof structure can be utilised for this. The flat of roof is large flat area that is usually unused.

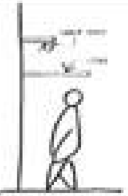
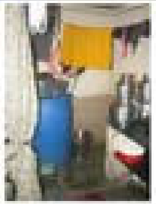
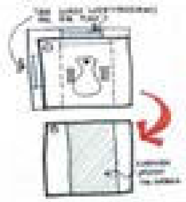
Case study observations and comparisions					
Sr. No.	Observations from Case study	Pictures	Surprise Factors	Inspirations/suggestions for Project	Initial ideation
1	Adaptive usage of space. Most of the storage happens in loft and below furniture. Also there are boxes to store garments in each house		Very few closed cupboards, all shelf storage open	Loft space advisable in house. If headroom constains then there could be smaller loft with 2 layers of shelf (utilising volume)	
2	There is bathroom in each house for taking bath. There is no toilet and one has to go to public toilet to use it		Bathroom is open from one side with curtains. Size of bathroom big compared to house size.	Main reason for this is space constrains for toilet, Privacy/odour issue in a small house and Plumbing. It can be resolved by Having toilets which can be covered and used as bathroom. For odour and ventillation issues corner sppace with ventillator on 2 walls improves ventillation	
3	shelves very common throughout the house		Just at the lintel level at entrance, Large storage shelf	ladder could be used as shelf. Also hanging openable storage below deck wherever headroom is not a constrait	
4	200lts water Barrel in almost every house		More water at house than expected	special water tank of cuboidal geomatory can be more space saving. Water tank advisable to be put above toilets & Kitchen	
5	compact kitchens with cooking slabs and ample storage above and below the slabs		all the vessels, Groceries and gas cylinder are housed in the specific place in their own "Modular Kitchen"	heavy duty kitchen slab is must. Washing and drying area can be combined and overlapping. Flexibility/options in standing cooking and sitting cooking to be given. Except cooking area all shelves advisable.	

Table 2a: Case study : observations and suggestions

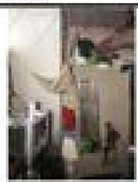
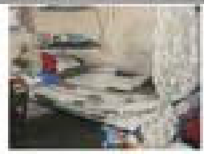
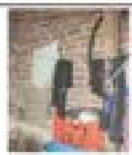
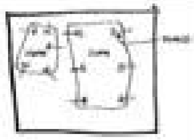
Case study observations and comparisions					
Sr. No.	Observations from Case study	Pictures	Surprise Factors	Inspirations/suggestions for Project	Initial ideation
6	Area below ladder used as bathing space		barely straight standing space used for bathing	Bathing space needs good headroom so slanted wall is not advised. Instead area below ladder is good alternative to loft storage.	
7	Bed not important, Sleeping on floor is more accommodating and comfortable		still people had bed and it covered almost 40% of house area	Bed takes up more space and most houses have 4+ number of people living. Foldable or collapsible beds can be good options as that will allow usage of the free space in day time and converting it into bed in night time.	
8	washing happens outside in common areas			In new design, provision for public washing areas can be proposed at architectural level as people can relate to it better	
9	Small recess in wall used in storing shoes		even small ledge created while wall changing of wall thickness used as cosmetic and shoe storage	Joints in members/Assembly details of furnitures can become interesting microstorages	
10	Ropes for drying clothes.They don't possess many clothes so main drying space required is for bed sheets and saris		Surprisingly less no. of drying ropes	Saris and sheets drying space to be designed specially. Roof structure can be utilised for this. Clothes could be fixed flat to roof structure using some arrangement to utilise the area and roof heat will speed up drying process.	
11	Bed occupies maximum spaces in the house			storage box could be used as bed or collapsibles also can be explored.	

Table 2b: Case study : observations and suggestions

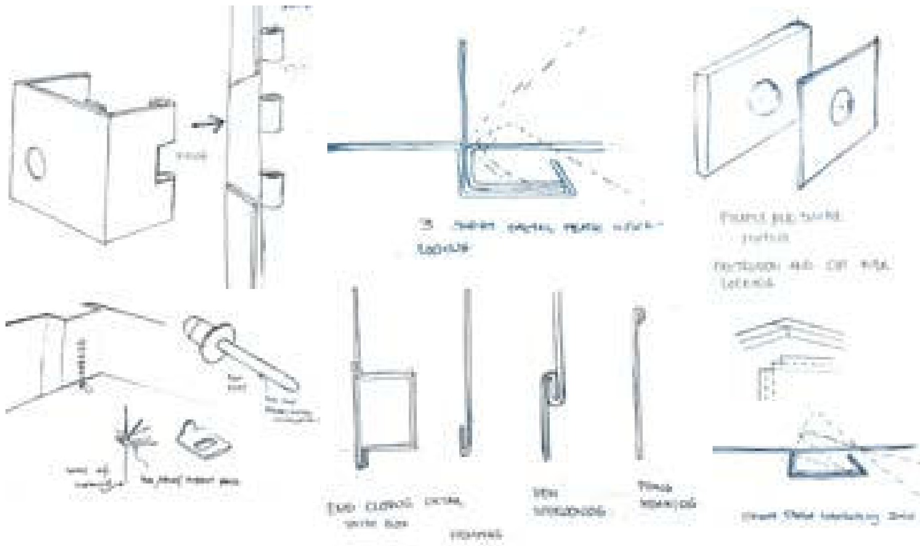


Fig: 11 Details of Knockdown furniture details

Fig: 12 Slimline cabinet. Picture taken from www.godrejinterio.com

Possibility of materials (Sheet steel)

Consideration of sheet steel usage in design

Sheet metal is a very versatile material and gives really strong sections while bent. Bent sections of sheet steel are easier to make then hot rolled sections and are more stable in comparison. Hence there was initial thought about using steel sheet metal for the furniture design of affordable housing solutions.

Manufacturing drawings/basic knockdown furniture study

as a part of my internship, i studied manufacturing drawing of Godrej interio cabinets for better understanding of Knockdown assembly and bending or strengthening of sheet metal.
I found out the importance of
Assembly Guidelines: Detailing out all sequence and process of assembly, Removing packaging and on site riveting
Important points to note:
•Seaming joints
•Fixtures
•Hooks
•Hems, Side bend and stiffener for stability
•Sliding and sequence of storage
•Decision to use spot welding and co2 welding
•Decision to go for knock-down product or wielded product

Types of Assembly fixtures in slimline cabinets:
•Various types off assembly joints are:
•Interlocking in bent sheet
•Protrusion and cut fixing
•Pop rivets and screws
•Hooks/ support pieces for shelf.

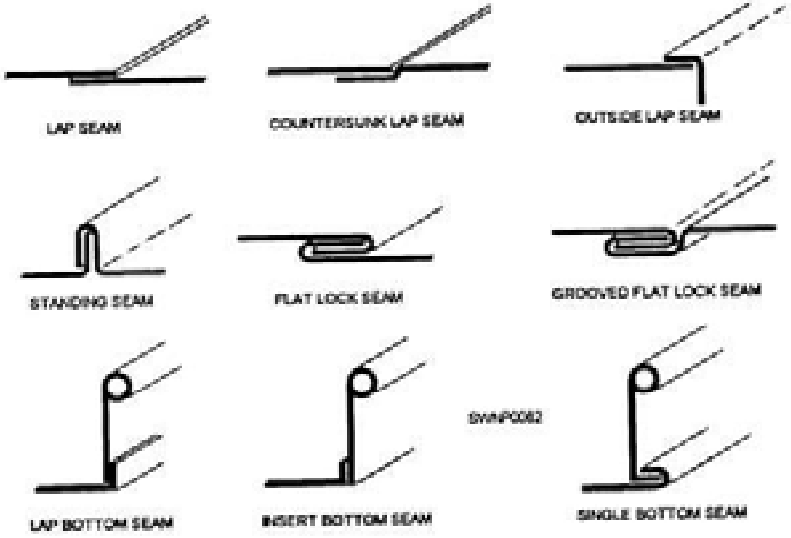


Fig: 13a Dry joints in steel sheet bent parts, pic taken from www.instructables.com

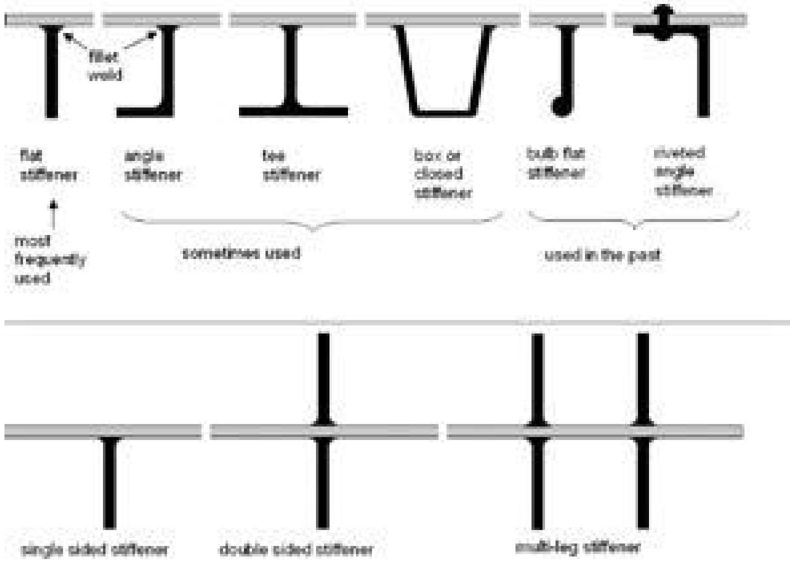


Fig: 13b Stiffeners in sheet steel www.instructables.com

Techniques to increase strength of sheet metal

Hems are created when you fold over the metal back onto itself. It saves time (less de-burring), gives a more finished look to your edges, and, most importantly, it adds tremendous amounts of strength to a face!

Beads are embossed lines that run across the surface of the sheet. These are made using a bead roller. These indentations add strength perpendicular to the bead. This is the idea behind corrugated tin roofing.

Grooved Seams are a great way to join two pieces of sheet metal, but they also create tremendous strength perpendicular to the joint. A properly grooved hem has 2 broken edges, and 4 layers of sheet metal in one spot.

Stiffeners are secondary plates or sections which are attached to steel sheet pieces to stiffen them against out of plane deformations. Stiffeners are used in controlling local buckeling Adding additional strength to the sheet metal section Provide shannels for concealed wiring or accessories fixing

3. Previously researched data

User studies

The user data available at IDC which was collected over a three years of time along with the project done by IDC batch of 2013-15 was used as a backdrop for this project. The available data defines the user category. It also elaborated the occupation, their annual wage and also about their lifestyle. Apart from this data, field trips were conducted to get a first hand experience of the life in slums. Through this field visit it was possible to see , socialize and learn about the people living in slums and who will be the major user category for this project.

Activity Analysis (based on the Volumetric housing prototype)

A brainstorming was done to analyses the spaces created in the project Affordable housing - fitting more in volume. Each and every space was analyzed in detail and based on the analysis some observations for effective storages, space saving and comfort were made.

Few of the key points are:

- Spaces are multipurpose, can be used in layers.
- People often are very poor and cant afford to put bigger investments so the investment could be in install.
- Small repairs can be done by them
- TV is central member of the house and holds very important location which is accessible to everyone in the house.

Fig: 13 86 sq. ft apartment, pic taken from www.homesandhues.com

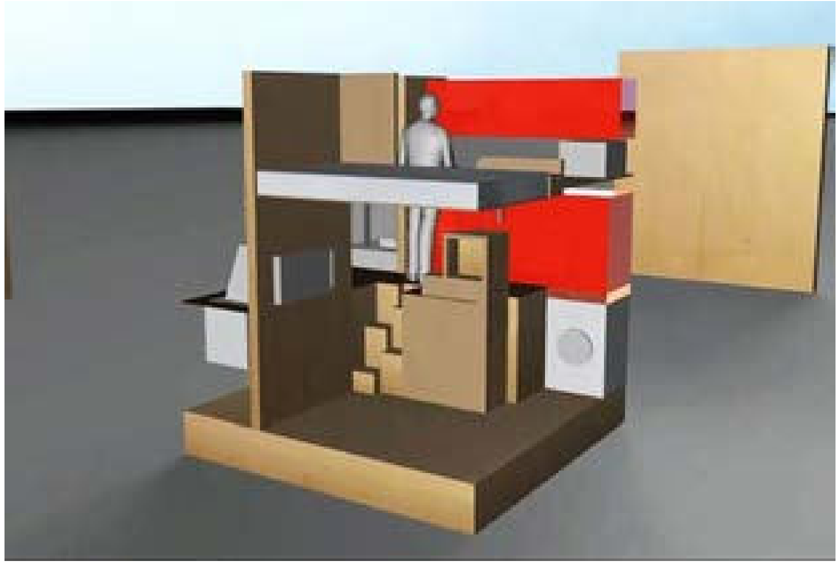


Fig: 14 Cube project, pic taken from www.pinterest.com

4. Parallel Project study

Different similar projects from across the world were studied to understand the perfect utilization of area and volume in different cases. Though many of these exmples are luxury apartments and might not be anywhere similar to the project i am doing, their spacial arrangements and vertical designing was inspiring for the project.

86 Sq ft apartment, Paris

The 86 sq.foot apartment in paris is an exampleof utilizing the space to fullest. rolling stairs and sliding doors ensure that there is always more space spaec than what is meeting the eye. The wall cabinet is a entire house. it has all storages, shelf, table/chairs and bed.
The design is based on the concept of swiss army knife, Multifucn-tional, foldable and compact.

Cube Project

The Cube Project is a low-energy micro-home project taken up and designed by Dr. Mike Page at the University of Hertford-shire.
Built under the name, QB and QB-2, the micro-home takes up very little carbon footprint and can accommodate a single person or even a couple. QB hasa footprint of 3mx3m, whereas in the extended edition, QB-2 has a footprint of 3mx3m and a clear height
of 3m. Even though, this is compact in size, it accommodates a ful-ly functional kitchen (with hob, oven and fridge), a 4m long galley bathroom, a living space with a two-seater sofa and two ottomans which can be converted to a dining when needed, a fully-sized

Fig: 15 IKEA furnitures, pic taken from www.flatpaxabia.com

double bed and ample storage space.
QB-2 ensures a highly insulated construction, low energy lighting and appliances. It is a post and beam structure, which can be assembled and made water-proof in around 4 hours and the entire structure can be completed in 3-4 days. QB-2, once constructed can easily be transported and fixed wherever a static caravan is permitted.
The most important aspect of QB-2 is that it is available as a do-it-yourself kit as well as a complete building at various stages.

Ikea furnitures

The fixing details of IKEA furnitures were taken as benchmark in the current project. Hence the fixing details are studied in details and if possible, the details of wooden joinery could be used in metal furniture. Also the easy DIY assembly of IKEA furnitures is important inspiration point.

Insights from parallel projects

From the case studies, we get better idea about how people around world are utilising small living space. Arranging these spaces intelligently and utilising vertical space effectively helped these people to solve the issues or negotiate with the problem of having less space. Also the sliding/folding 86 sq,ft, house furnitures tell us the possibility of designing space .

Fig:16 Incrementality in bed illustrated, Simple bed converts to bunk bed

Design criteria

Based on the data collection and initial study, a few criterias have been identified which will be very important factors in designing process. These design criterias are:

1. Incrementality

Incrementality is the main factor considered while designing as the consumer is mostly a new immigrant to the city and often has shortage of money. They wouldn't be able to buy the whole furniture system together. The furniture system should be such that it could be built in stages. There can be just the toilet and kitchen with sleeping on floor initially. Then as and when required, new furniture could be added to the system.

2. Flexibility of layouts/assembly

Very often, the layouts are fixed for a slum redevelopment housing. Hence the people living in the house can't change the layouts. This makes their choices very limited and most of the house ends up looking same. Also there is no choice for the dweller to choose where they want bed and where kitchen. This project will allow the people living in the housing to choose the layout they prefer. The same components can be assembled in different ways to achieve various layouts.

3. Joineries/detailing

Another important factor in this project is to create joineries and structural elements such that it can be utilized in various forms and can have multipurpose usages. IKEA joineries are studied and taken as reference for this.

4. Vernacular aesthetics

The people living in slums are mostly coming from villages and have their own aesthetical sense which is different from people of city. We should be able to provide opportunity to the people to customize their dwelling based on their vernacular preferences. Also the materials used should be something readily available in that area.

5. Multipurposeness/flexibility

Each and every space created in the house should be multipurpose In line with the practices currently existing in slums. Most of the areas of a slum house is effectively used for various purposes and that is morphed into the design of furniture system.

6. DIY Self-assembly/lightness

To reduce the cost of the product, mass manufacturing is very important. This gives importance to modularity and DIY assembly. If people are buying components and assembling it themselves, the cost reduces drastically. Keeping the components lightweight is very important for doing DIY assembly.

7. Cost/Economics

Finally, the most important factor in affordable housing – furniture design is keeping the economics at correct position. The cost is most important factor and has to be managed. The cost could be broken down into parts and phases so that the person buys components phase wise as and when they afford it.

Design Brief

Design an affordable do-it-yourself (DIY) furniture system for volumetric houses (houses with vertical space utilization) in Urban Slums for bottom of the pyramid people.

- The furniture system should be Able to accommodate the time based changes in needs of the user.
- The furniture system should be modular with details designed keeping modularity as base.
- Flexibility in arrangement of components (layouts) should be possible with the same components.
- It also May use existing joints and mechanisms
- The assembly should be simple and easy to learn. Minimum number of tools should be used for assembly.
- Some spaces or components could have multipurpose usage based on time and user.
- There should be minimalspace wastage in the assembly.

Scope of the project

The project, together with previous project of affordable housing - Fitting more in volume aims at the housing needs of people at the bottom of the pyramid, whose annual average salary is below Rs.90,000 at the 'start' level, where he has a small family (or him being single), which can increment slowly. Considering the already existing space constraints in the cities, the project looks at utilizing the available space in the most efficient way.

The current project looks into developing furniture system which will fit into specially designed shell of volume 10'x10'x12.5' keeping in mind affordability, sustainability, better storage and hygenic conditions.

Limitations

since furniture approach is taken, there is certain freedom in the project from DCR and bylaws but minimum standards for dimentions are followed as much as possible.
Keeping it affordable, modular, sustainable and incremental brings in complexity to the project

Deliverables

- Proposed design solutions
- full size working model
- Demonstration of working of the system

Layout design

Most important part of the project was to redesign the layout to suit the current requirement of incrementality, Flexibility and extension to various other sizes. The layout design started with finding out the requirement for a family.
The Layout done at this stage got slightly modified at concept development stage to become final layout which will be explained later in the report. The changes in the final layout were done based on the various design approaches followed.

Few assumptions taken while doing initial Lay-outing are:

- The fixing details of furnitures is not finalized
- Furniture could be wall attached or floor standing
- One wall of the room is outer wall of the building and opposite wall is the corridor side wall with access to the house
- Plumbing lines go in the outer wall

Requirement for family of 6

Based on the slum visit and previous studies, a requirement for household of 6 people (couple+2kids+parents) was derived. It has been done keeping in mind the testing results and success rate of previous project of Affordable Housing – Fitting More In volume. The Basic requirement is of a bed, Kitchen counter and shelfs, Chairs and Toilet at the lower level and further extension of 2 more beds, storages, study table and mezzanine platform at upper level.

Natural lighting, ventilation and plumbing lines

The location of kitchen and toilets is majorly dependent on the natural lighting, ventilation and plumbing lines. Hence toilet location in all the layouts is kept stationary. Location of kitchen is varying but taken into consideration is the fact that it has to be close to the toilets.

In one of the layout the kitchen is towards corridor and hence that will not get direct window to outside but will get ventilated from the corridor side. In that case, there will be window at the upper level (above mezzanine platform) too to enhance ventilation.

Plumbing lines have to be laid along the outer wall and hence toilets are limited to the outer wall alone. To reduce the plumbing lines length, its better to minimise the distance from toilets to kitchen sink. This factor is considered while designing the layouts.

stage 1

stage 2

stage 3

stage 4

stage 5

stage 6

growth of house from 0 years to 15years in incremantal pace.

Incremental growth in timeline

As discussed earlier, the house grows with time and the furnitures can be bought in phases. This is made possible by creating components and providing DIY assembly. Incremental growth was the biggest factor while designing of the layout as the components could be used for different purpose at different phases. A stage-wise incremental development idea is mentioned in Fig.

Progress in years

0 Stage 1: roof, toilet and Kitchen.

1 Stage 2: Single bed and basic storage

5 Stage 3: Bunk bed, small ladder

8 Stage 4: Attic level, foldable chairs

10 Stage 5: Storage cabinet, extra tables

15 Stage 6: Foldable bed at lower level, appliances

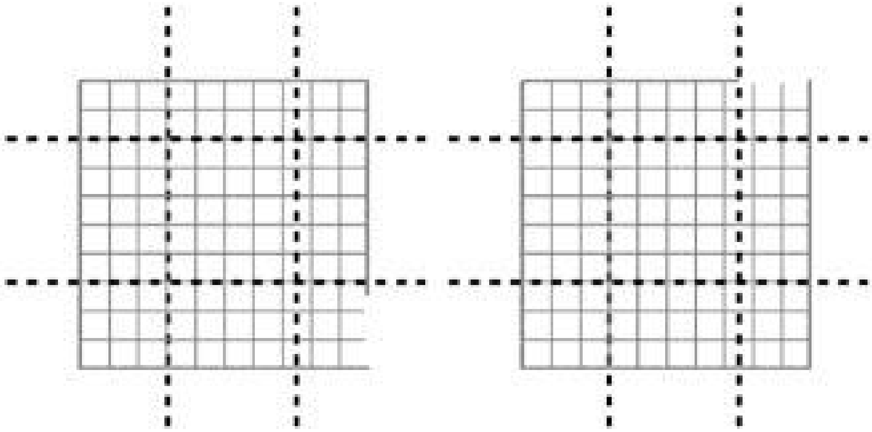


Fig: 18a. Above: the initial grid exploration (3', 4.5', 2.5') in y axis.

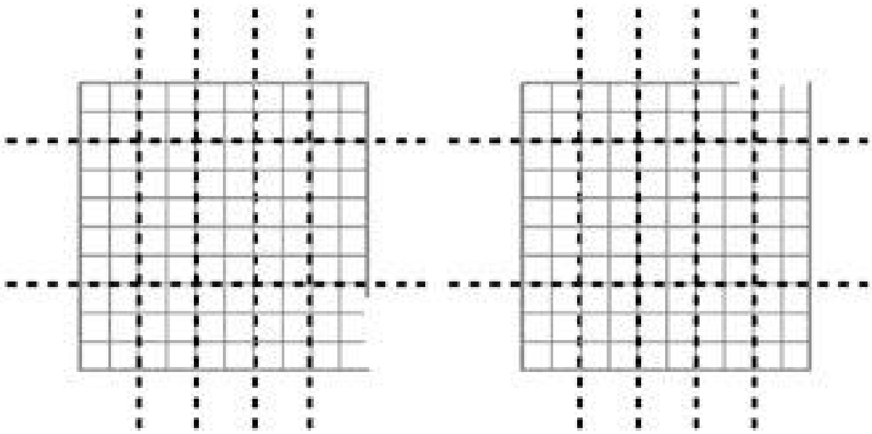


Fig: 18b. Below: slight change in the layout (2', 2', 2', 2', 2')

Grids

Basic minimum dimensions of furnitures are noted based on the codes requirements and previous project on affordable housing. On basis of these dimensions, several basic grids were explored and a basic grid of 3', 4' 3' x 2', 3', 5' was finalised. To verify the effectiveness and success of the grid a exercise was carried out where tracing paper was overlaid over the grid and all the possible location for beds, kitchens, ladders, storages and TV were marked for both the levels. Post this exercise, the mix and match technique was used to pick up bed locations complimenting kitchen and storage locations and several layouts were derived. Once deriving layouts minor changes to the grid was done again.

Pros of grid:

- provides template for furnitures to get fixed.
- standardised Grid can allow various furniture arrangements possibilities
- furniture becomes kight as load is taken my wall frame laid along grids

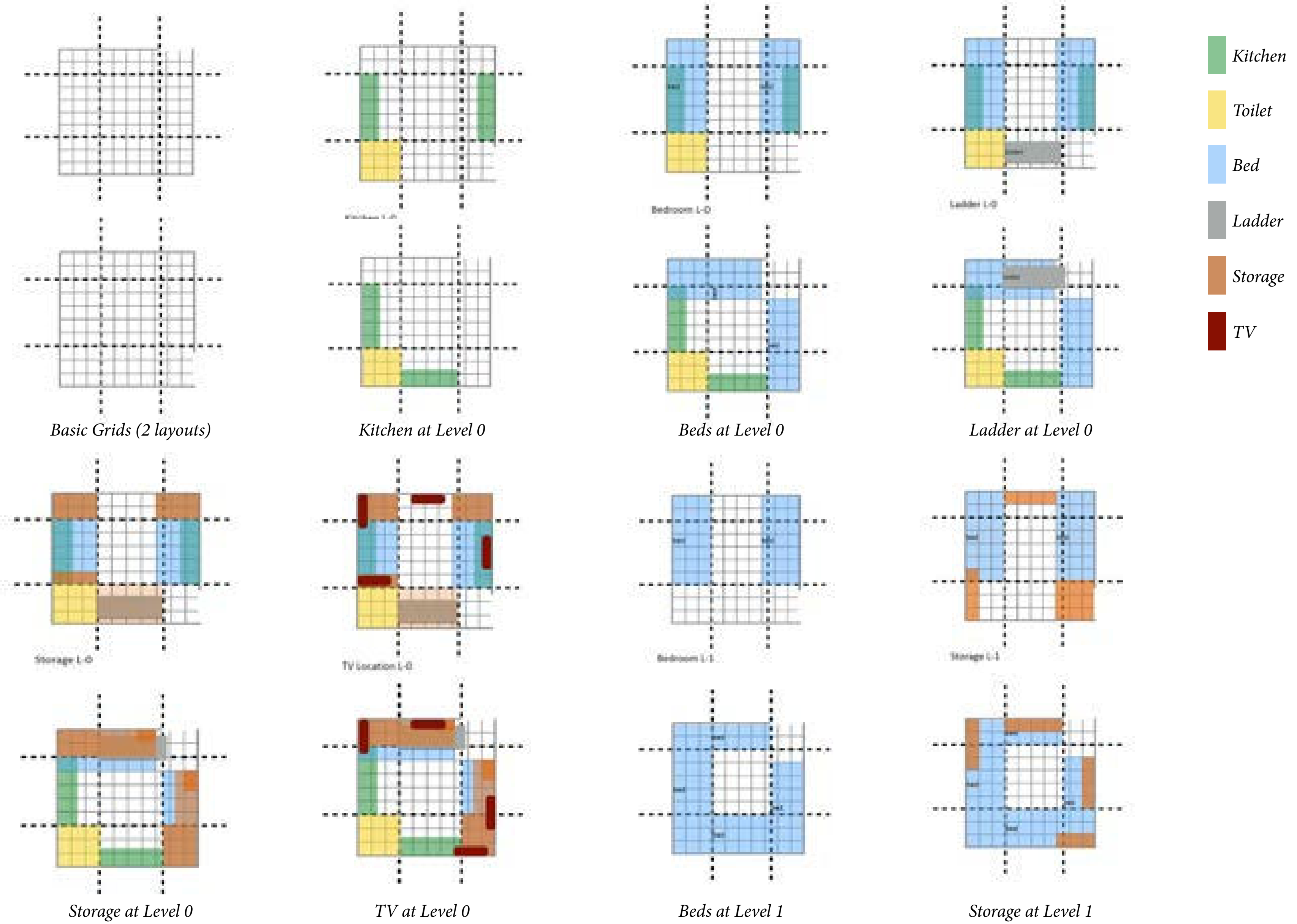


Fig: 19 Explorations in the grid to find possible locations of furnitures.

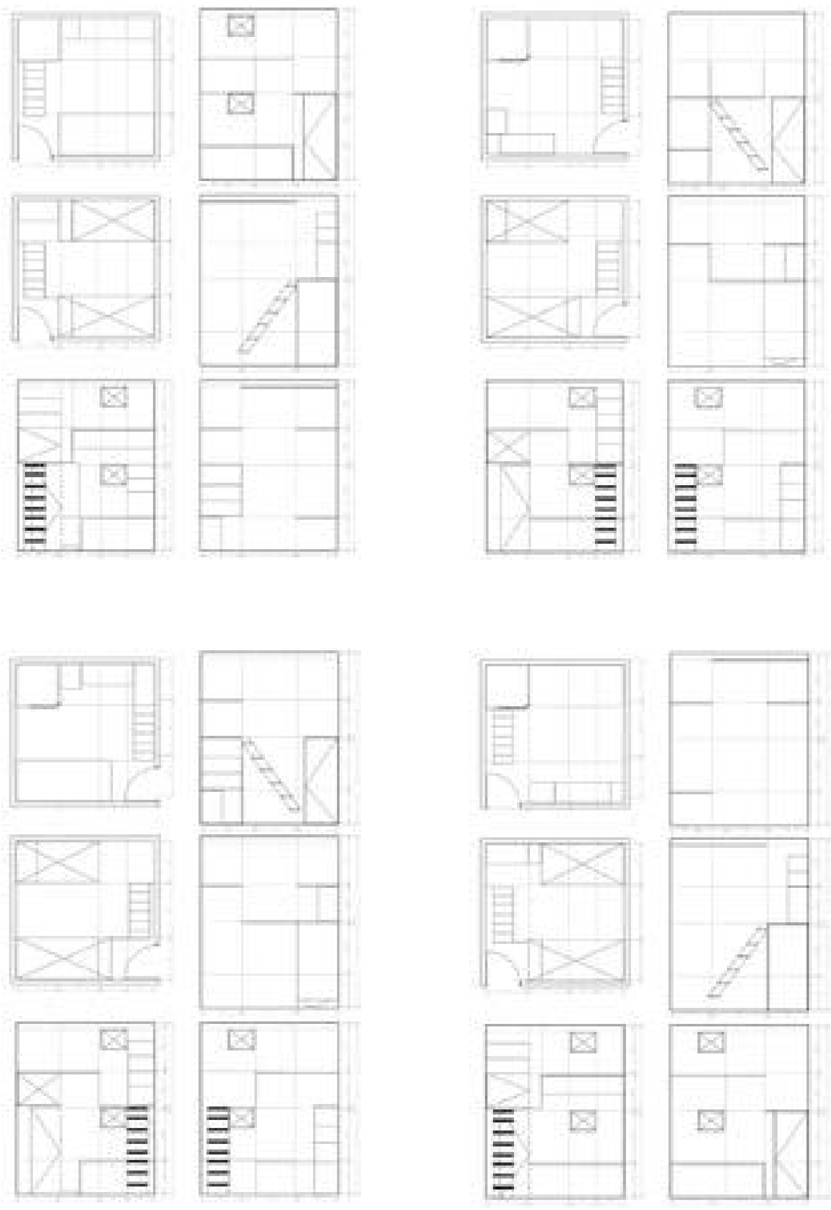


Fig: 20 Layouts explorations with elevations

Explorations

Explorations based on the grids were done for layouts. The layout with all wall elevations was made keeping heights same as the previous year affordable house project. While exploring the layouts, the possibility of making slight variation in the layout of ground floor houses to suit the requirement of the houses with openings from the outside was discussed.

Houses with openings from outside:
In this layout, the door has to be towards outside wall but all the floors above will have doors to the inside wall itself. Hence the toilets location has to be retained at the same place and without changing the toilet location this layout had to be integrated in the design. While integrating this layout, small changes with grid dimensions were made.

Possibility of shifting kitchen to upper level:
Another possibility of shifting the kitchen to upper level was discussed at the exploration stage. The issue with this possibility was this might create hindrance in incrementality concept but the possibility that kitchen stays in lower level when house starts and moves to upper level when the last phase comes up created path to several options. The benefit of moving kitchen to another level was
1. The distance from toilet increased hence psychological fear of cooking next to toilet gone
2. Space saving at both the levels
3. The lower level could be used as income generating space for some small industry. Kitchen gets privacy

Bed & kitchen parallel

Bed & Kitchen perpendicular

Final Layouts

The final layout was giving possibility of 5 different arrangements with the same components. The components were not designed at this stage but were assumed to be wall attached for convenience. The first arrangement (similar to previous years affordable housing project) had bed and kitchen parallel to each other. The second and third arrangement had Bed and kitchen perpendicular to each other and the Fourth arrangement had entrance from outside. This arrangement was possible for ground floor only. Finally fifth arrangement had kitchen going to the upper level at the last phase of construction. This arrangement of course required few extra support but was very effective in spatial arrangement.

Bed & Kitchen perpendicular 2

Kitchen shifted to upper level

Ground floor unit (entry from outside)

Fig: 21 Arrangements using same components derived after the explorations

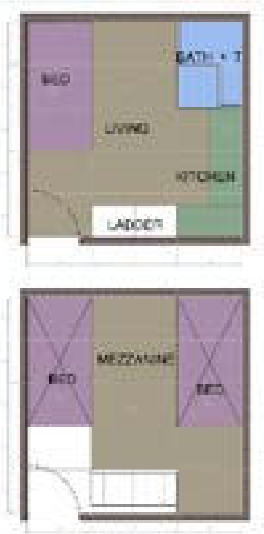
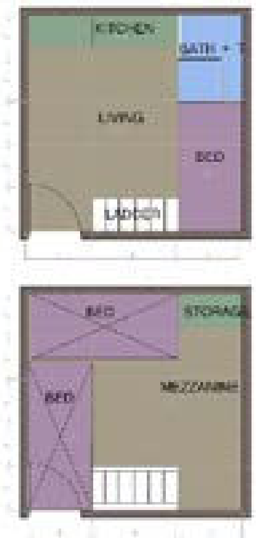
	Layout 1	Layout 2	Layout 3	Layout 4	Layout 5
Layout plans					
Floor area left in ground floor (in sqft)	55	32	45	58	48
Floor area left in loft floor (in sqft)	32	38	35	49	43

Table 3 comparision among layouts.

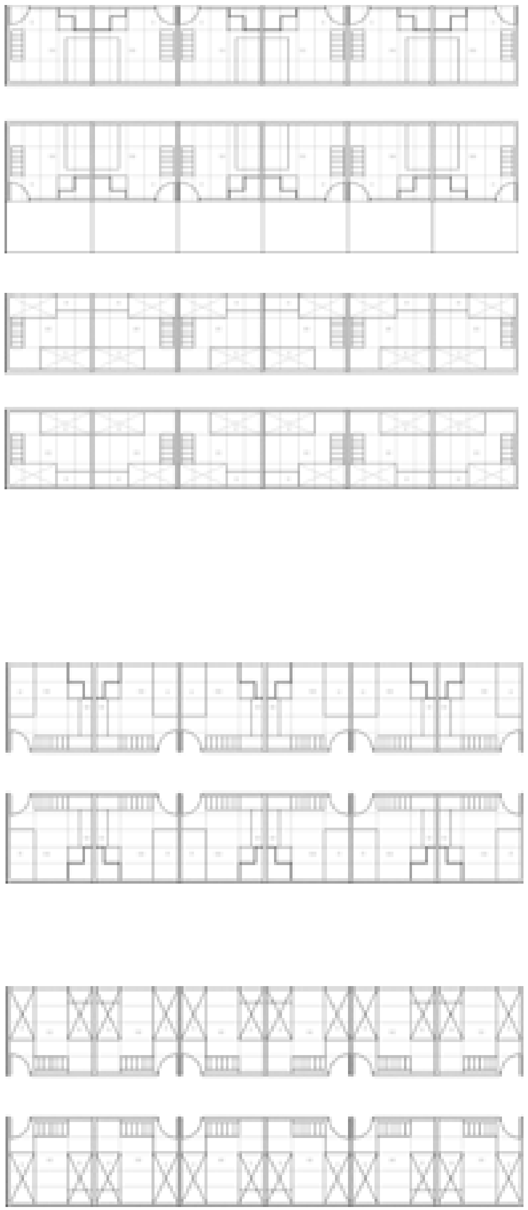


Fig: 22 Clustering possibility in ground floor unit (above and staff units (below)

Clustering

The clustering of the houses were mainly explored in linear pattern. Since its out of scope of this project, clustering is discussed in very brief and is just suggestion for the project. There are two possibilities for clustering. One is when the entrance of ground floor is from outside and in all other floor its from inside. In this case all the houses are lined in linear way and have entrance from both sides. There is a narrow passage in centre also for storage and access to above floors. The consecutive houses are mirror imaged so that the toilets are together for easier plumbing.
The second clustering is the conventional apartment type arrangement with all the houses entrance from corridor side. One benefit in this arrangement is that the space between two buildings is minimised as the space for outside space for the house and Road does not have to be considered.

Extending the layout to 10’X12.5’X12.5’ and 10’X15’X12.5’

This is one suggestion for the future Product range creation. The space constraint in a city like Mumbai is much more severe compared to that in tier 2 cities like Bhopal, Ahmedabad or even the suburbs of Mumbai like kalyan or karjat. So for the places where bigger space is a possibility, we can look into making the house go bigger with extra facilities coming. So the other two sizes considered are 10’x12.5’x12.5’ and 10’x15’x12.5’. the extra space coming out is effectively utilized in creating better free movement spaces and more storage spaces.

List of furnitures proposed post layouting

- Beds for top floor (2nos 3'x6')
- Bed for ground floor (1 no. 2.5'x6')
- Kitchen slab unit (4'x2')
- Kitchen storage rack 1nos.
- Chairs for Ground floor (4 nos. read)
- Study chair in 1st floor
- Table in ground floor – 1no
- Table in 1st floor – 1 nos
- Water tank
- Drying area
- Pooja Shelf
- Under ladder storage
- Attick stofa
- Under bed storage
- Clothes cupboard
- Tv rack

This list acts as provision only. Finally its upto the people to decide what to buy and when to buy.

	pros	con
Integrated approach	Structural stability. Cost effective, easier folding joints, floor space savings, grid approach with standardised furniture	Tideous to assemble and move, Furniture location in house fixed and can not be moved, strictly as per grid, Furniture cant be taken along
Independent approach	Under furniture storage, Furniture moveable and layout can be changed easily, joineries simple with less triangulatio Familian	Costly, Floor space utilised, folding difficult

Table 4 comparing integrated approach. in todays time,

Conclusion:
Independent approach, though slightly expensive compared to the integrated approach has greater advantage in terms of being independent of walls, easy movements and assembly.

Furniture Design Approach

Designing of futnitures was done taking three main approaches in mind. Each of these approaches are unique but will finally assemble into the final Layouts. All the concepts are designed taking into considerations DIY assembly, Least moving part, Incrementality and flexibility in layout.

The phase wise development layout for each approach were made with some basic joinery detailed outlined. The feasibility of each approach was studied and detailed.
Further, comparison and analysis of each approach was done on the basis of the evaluation criteria.

Fig: 23 House with all components fixed to wall

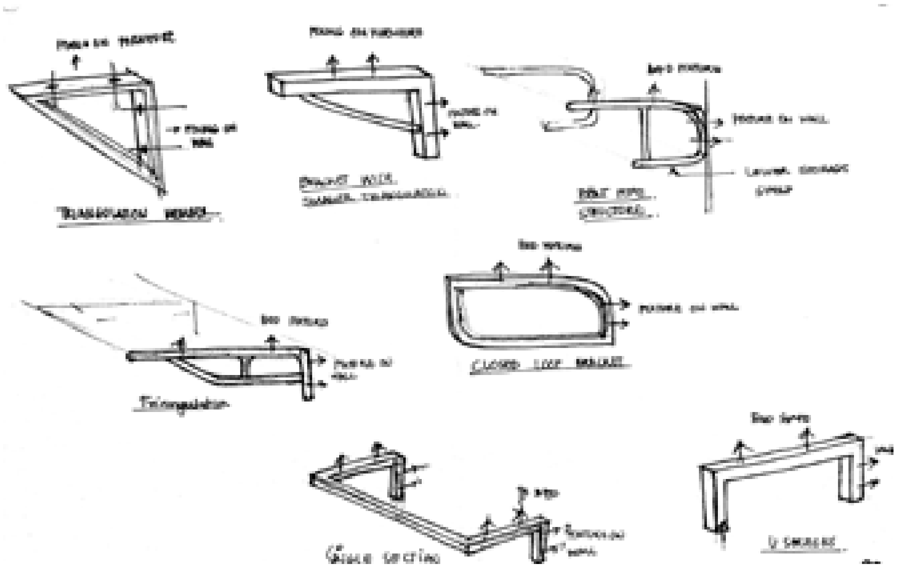


Fig: 24 : Explorations of brackets

Concepts:

Concept 1

In wall fixed furnitures approach, the furniture components are fabricated in factories. The furnitures will then be fixed in the frames already laid around the wall. Deciding a grid is very important in going ahead with this approach. The furniture components can be supported using brackets and are fully detachable. For this approach, ideations on brackets and fixing details were carried out individually. The ideations are shown in Fig. 31 and 32.

Pros:
- Easy to fix
- Each unit independent of other, easy to manufacture

Cons:
- Dependent on wall
- Many different furnitures required
- Lot of triangulation and structural framing required

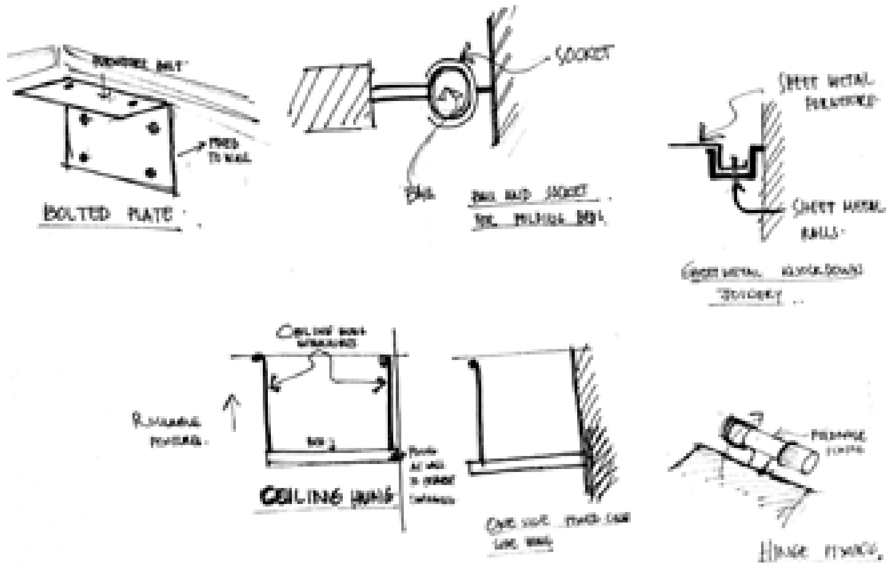


Fig: 25 : Explorations of joinery details for bed

Fig: 26 : The concept of flexibily and incrementality being demonstrated in model

Loose Furniture Ideations

For the wall attached furniture system, there was also possibility of loose furnitures directly resting in ground in the lower level. There could be foldable or multiusable beds, small shelves and cabinets etc. All the furniture has to be self-assembled.

Given are the few ideations of various types of beds that could be put upto multiple usages in the small ground level/lower level area. There are possibilities of bed getting converted into bunk beds at phase 2.

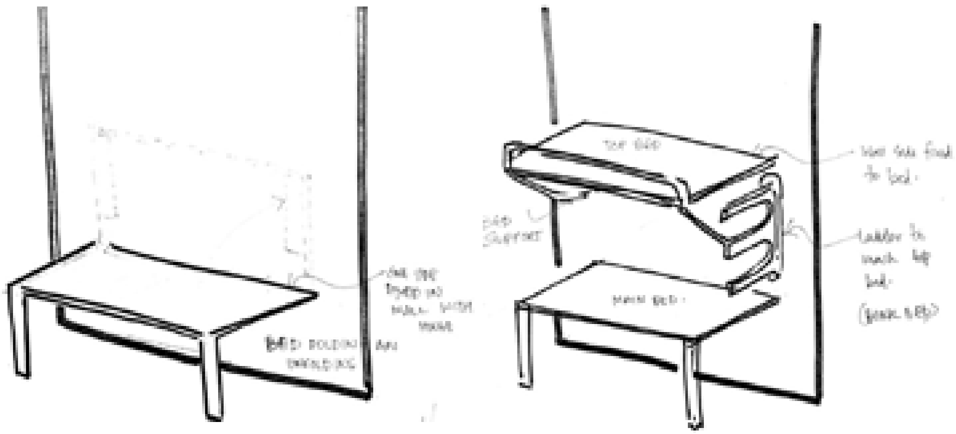


Fig: 27 : explorations of folding bed

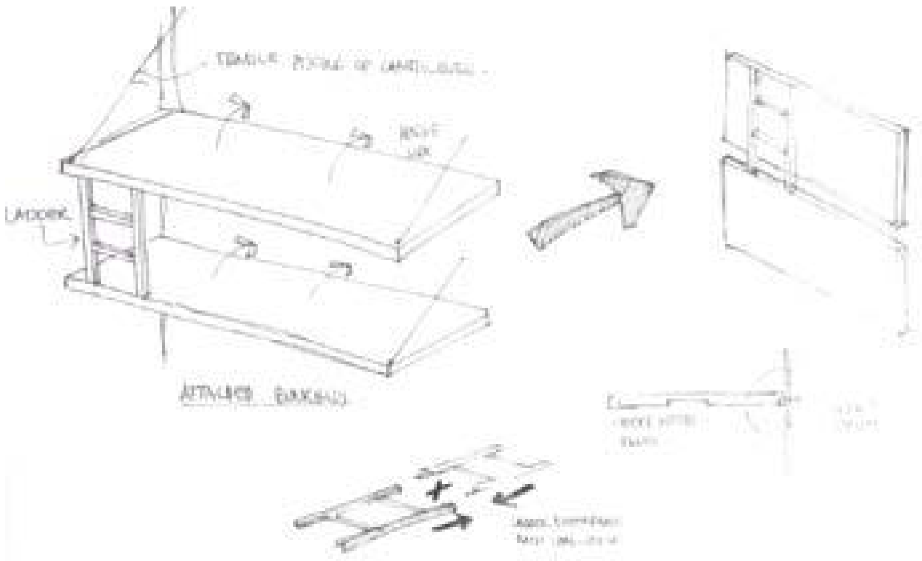


Fig: 28a explorations of folding bunk bed

Fig: 28b 3D view of folding bunk be

Few bed ideations for the upper level also fone using some non conventional materials. Ease of manufacturing, Economy, Storage space and multipurposeness are main factors forming the basis.

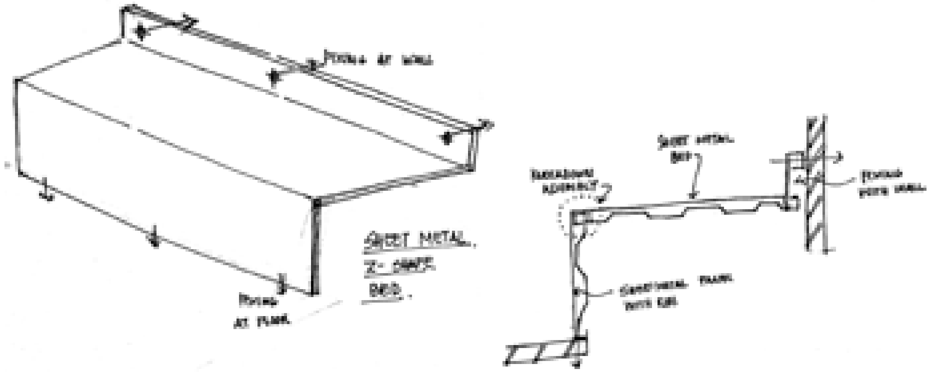


Fig: 29a explorations of sheet metal bed

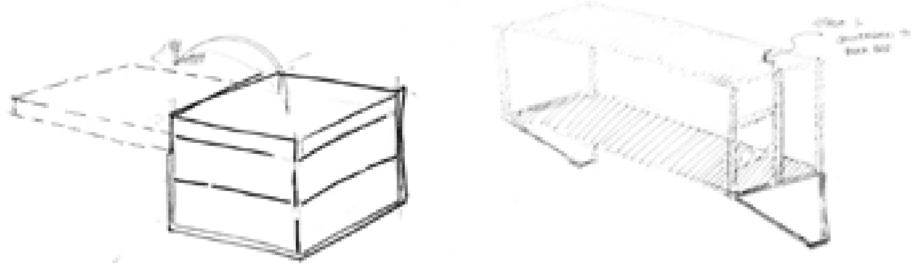


Fig: 29b sofa cum storage cum bed

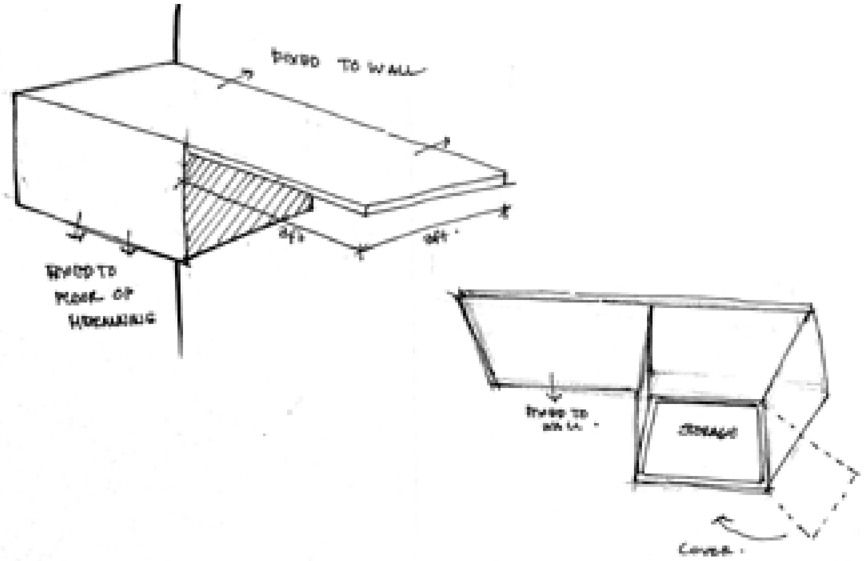


Fig: 29c explorations of upper level bed with storage below

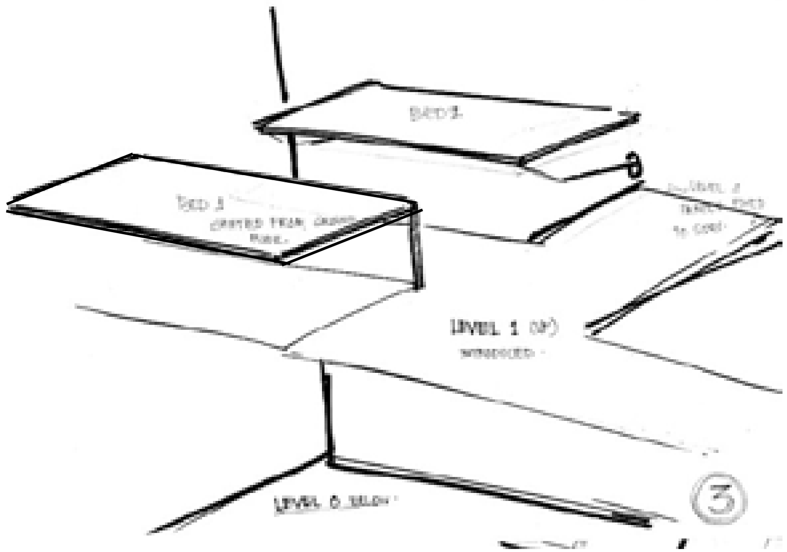
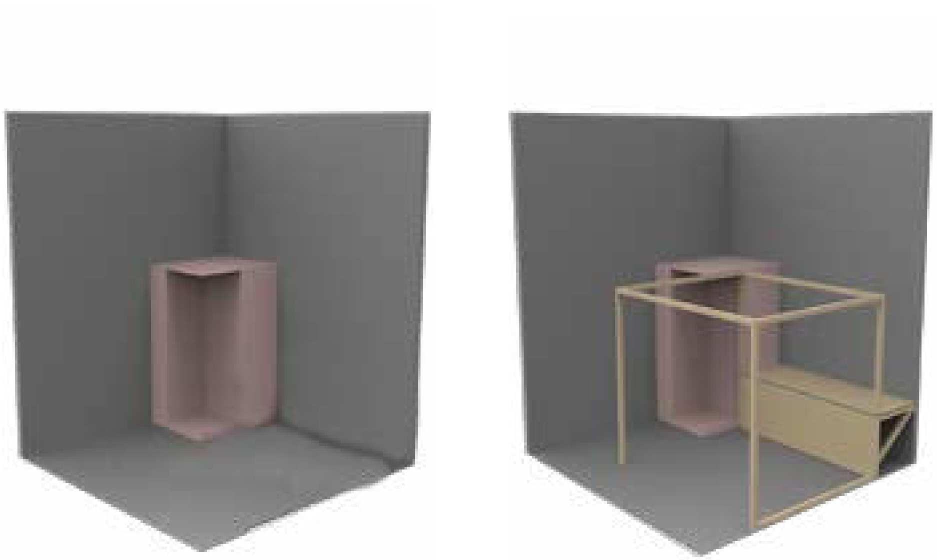


Fig: 29d exploration of upper level bed

Concept 2

In second approach a central core was used as main structural member and wall framing as well as dependency on wall is removed totally. All the components will be fitting either inside the frame or cantilevering with the frame. Slight change in layout to be done to accommodate all the arrangement possibilities. The growth of happens in 3 phases.



Pros:
- Structurally stable
- Less no. of columns
- Central frame supports all furniture

Cons:
- DIY assembly tedious
- Cantilevers might make structure unstable
- Rolled sections heavier

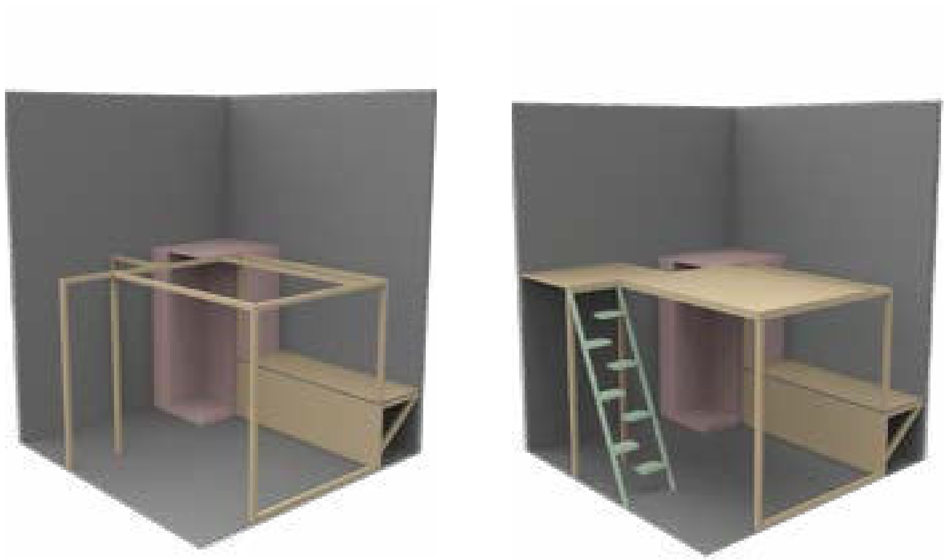


Fig. 30 Time based stage by stage development of furniture system in central core structure approach

Concept 3

The third approach to furniture design is floor standing furnitures with no support from walls. This is very unique approach as there is no hot rolled beam in the structure. The whole structure is Sheet metal bent steel sections. The platforms are sheet metal bent panels with each side bending depth as 3 inches. Thus a C channel is formed on all sides which acts as beams and gives stability to the whole structure.

Pros:

- Avoids dependence on wall
- Less usage of steel/hot rolled sections in beam avoided
- Various layouts possible

Cons:

- Structurally unstable
- Many legs below mezzanine area
- Panels are getting really heavy for DIY

house with toilet and kitchen

Stage 1

Stage 2

Stage 3

Fig. 31 Time based stage by stage development of furniture system in Floor standing self supported system approach

Stage 4

Stage 5

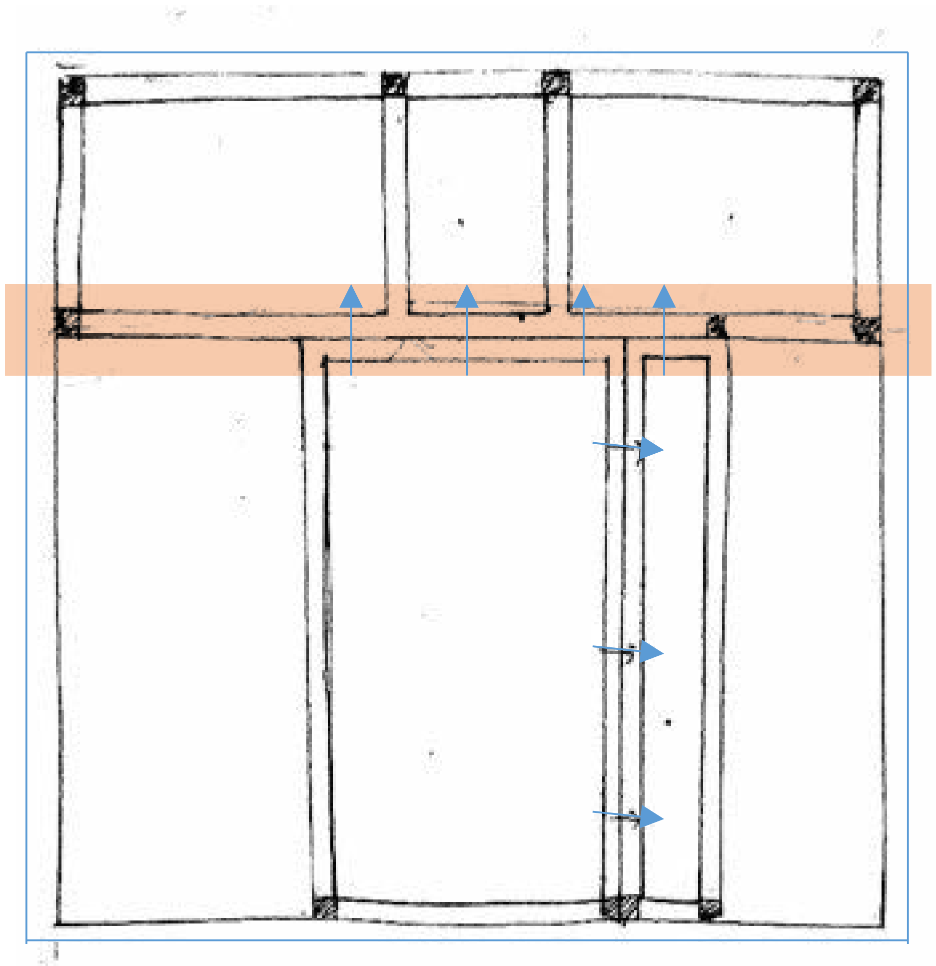


Fig. 32a mezzanine level plan showing the area where two panels are joining perpendiculy with no leg support below.

Issues and factors

- Leg support can be given only at wall sides. Hence many critical load points at centre are without supports.
- Panels bent on side act as beams (C Channels).
- Panels attached to each other supporting the entire structure structurally. These points where two panels are attaching with each other is structurally very weak and won't take creep for longer duration.
- Panels simplified and sizes made larger (through and through) to provide leg support at maximum corners of panel to make them stable.
- Structural load comes in the joining line. The most crucial factor about this design.
- Edges designed for easier assemblu in DIY

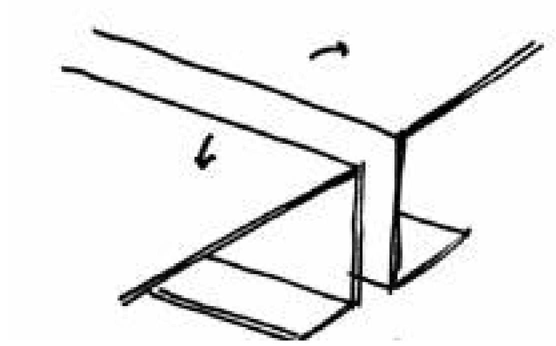
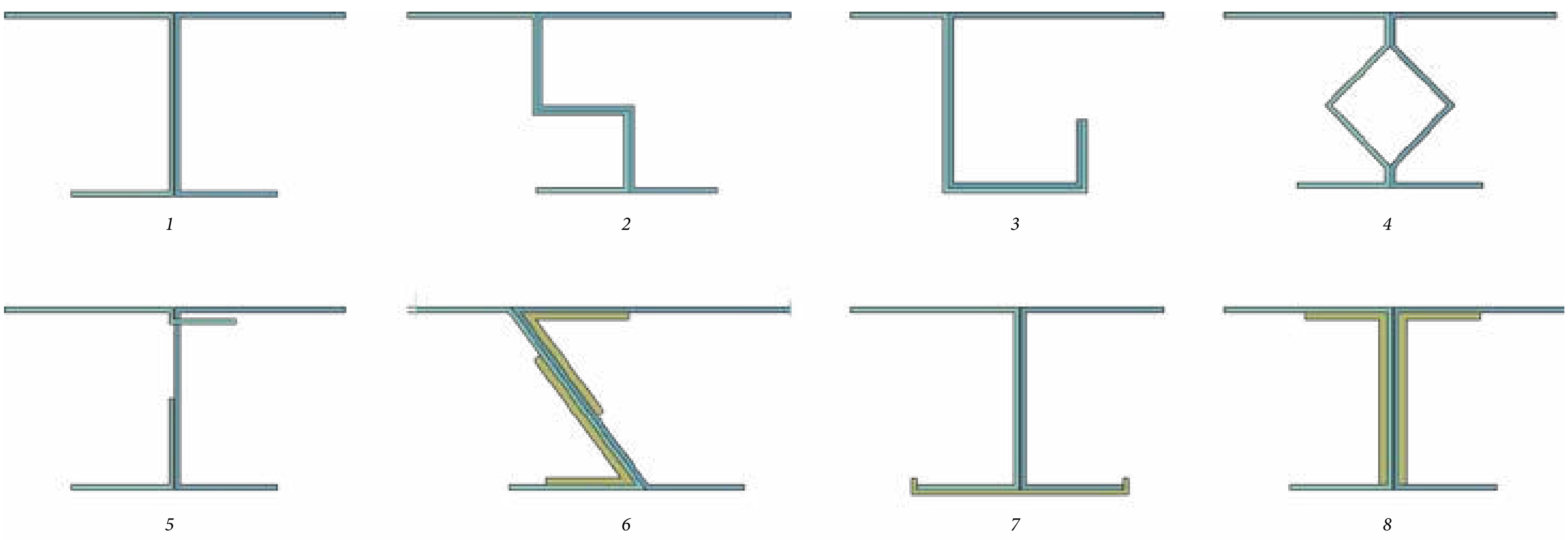


Fig. 32b sketch showing the creep acting on the joinery



Strengthening of sheet metal Panels - Edge Profiles for bending

- Several edge detailings for the panel bending were ideated. These were mainly designed to facilitate Assembly and increasing strength of joining.
- For each edge profile the depth is taken as 3 inches .
- In some of the details, extra angle sections or plate are added for reinforcement.

Fig. 33 Edge profile explorations for SS Sheet panel bending. Fig 1, 2, 3, 5, 9 and 10 show strengthening by different simple bendings. Fig 4, 6, 7 and 8 show strengthening using separate element.

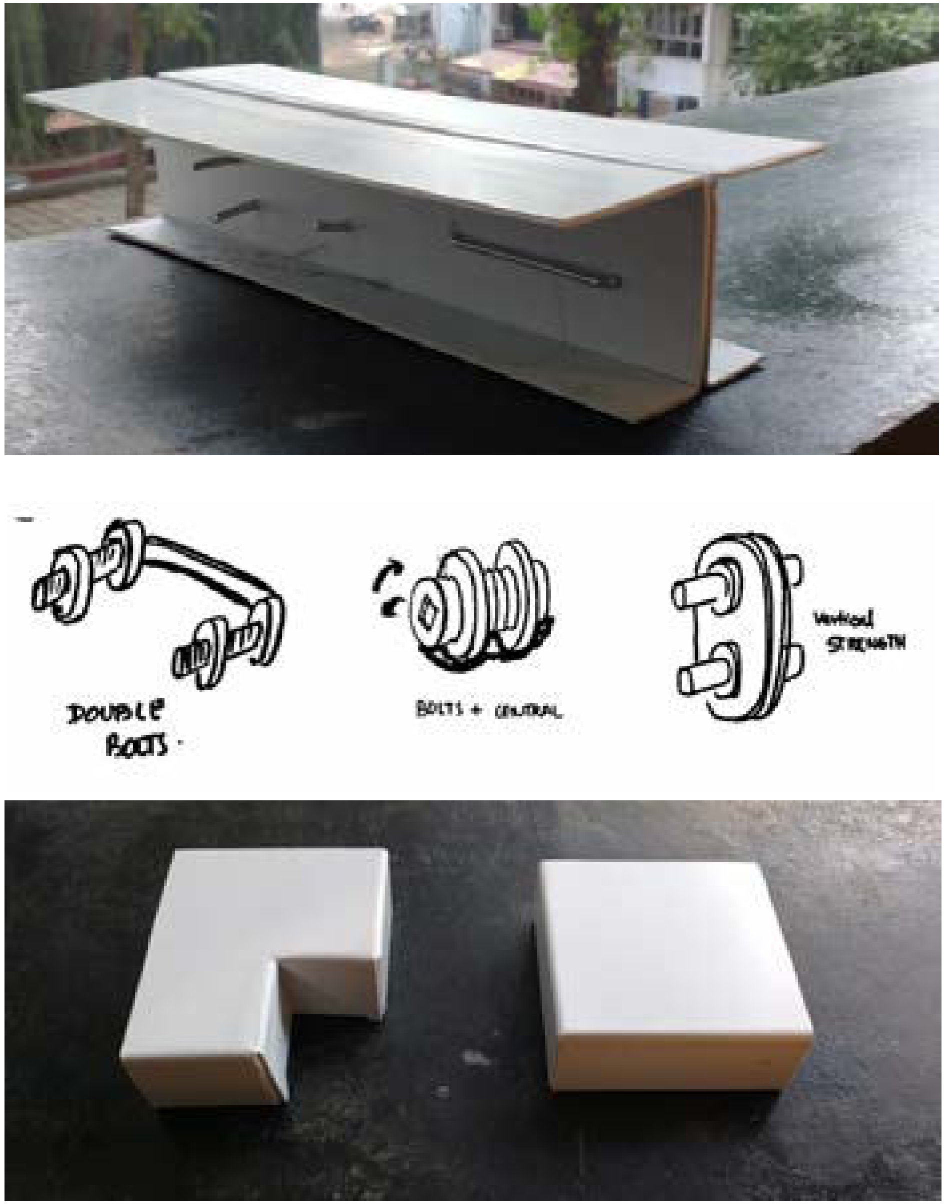


Fig. 34 From top: an exploration of bolts for the joining of two panels, corner explorations for leg to fix in.

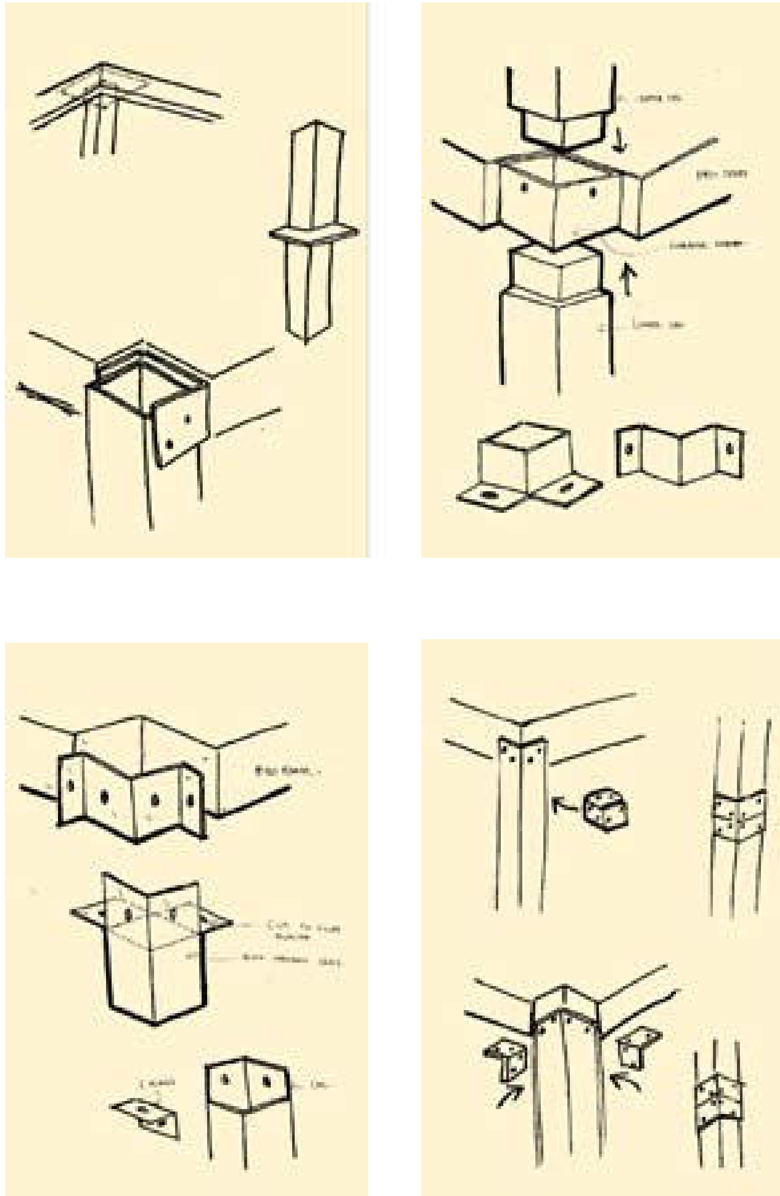


Fig. 35 Explorations in fixing details of leg to panels (in beds) and its vertical extendibility.

Fig. 36 Development of various arrangements of the furniture stage wise in 1:10 scale model

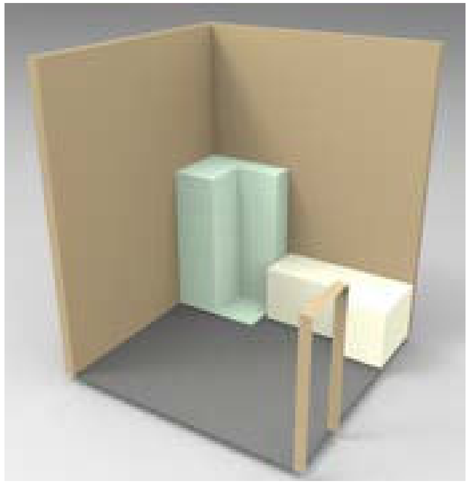
Concept evolution

criterias	Incrementality	Flexibility of layouts/assembly	Structural stability	Multipurposeness/flexibility	DIY assembly/lightness	Economical
	High	high	medium	high	medium	medium
	medium	low	high	low	medium	high
	high	high	low	high	high	medium

Table 5 Concept evaluation

Conclusion

- Concept 2 saves space but flexibility of layout is slightly hindered. Also if made better DIY design, this concept will become most economical and structurally stable.
- Concept 3 is flexible and good in DIY, multipurpose but not very structurally stable
- merger of details of concept 3 into idea of concept 2 can generate better feasible design



No extra furnitures

Bed with ladder

Mezzanine platform added

Finished structure with bed and table

Fig. 37 Time based stage by stage development of furniture system in new layout

Further design evolution:

- The design is evolved around the concept of using the central core structure as support for all components.
- To achieve flexibility of layouts, minimum 3 different arrangements should be possible in the design. The layout is changed slightly to achieve it.
- To reduce the weight of structure, Trusses/triangulation is explored.
- Design of ladder and landing changed. Ladder last step is 1' wide and from there the person directly takes 10"rise sideways to reach mezzanine level perpendicular to it.
- The new ladder arrangement helps in saving landing and circulation space at upper level. Bed can be brought immediately in front of ladder and in first phase of development of house, only the bed and ladder can be installed. Later the mezzanine can come in further phase.
- Joineries detailed for easier DIY assembly and better aesthetics.
- Cold formed bent Closed C section used for all columns and beams.
- Trusses simplified for easier manufacturing and better aesthetics of the structure.
- the structure doesnt support any furniture at lower level.

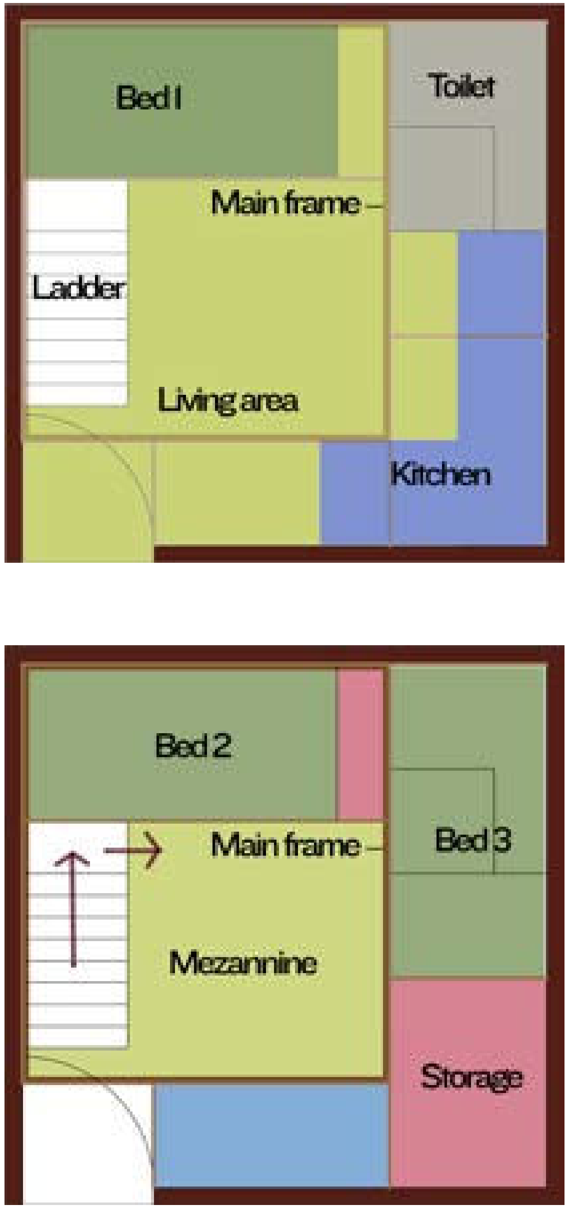


Fig. 38a Arrangement 1 based on new layout. Ground level (above) and mezzanine level (below)

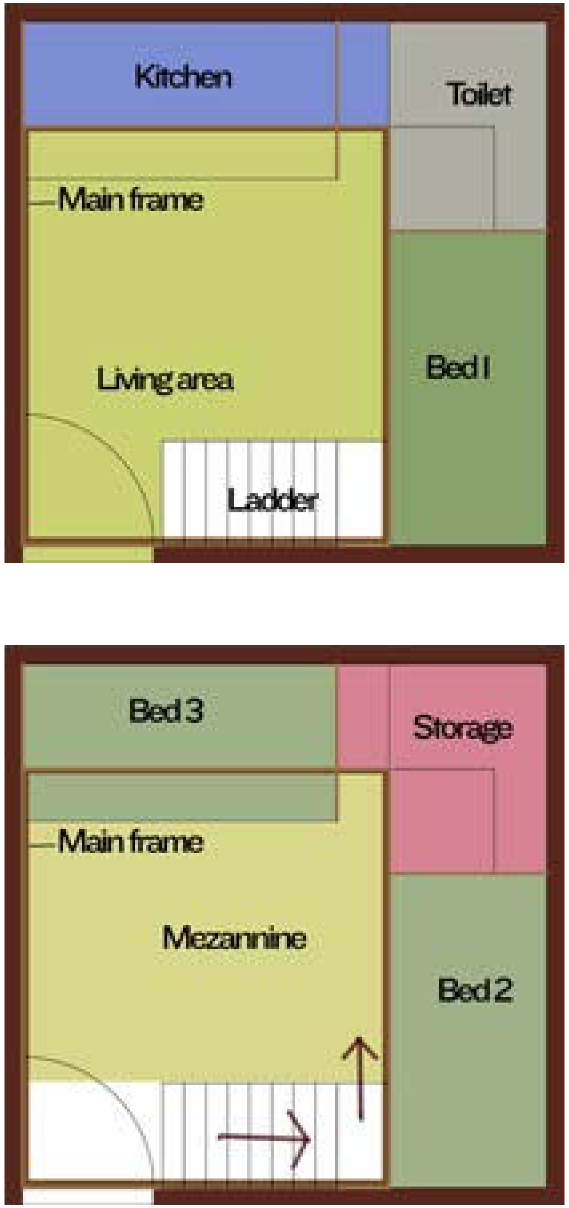


Fig. 38b Arrangement 2 based on new layout. Ground level (above) and mezzanine level (below)

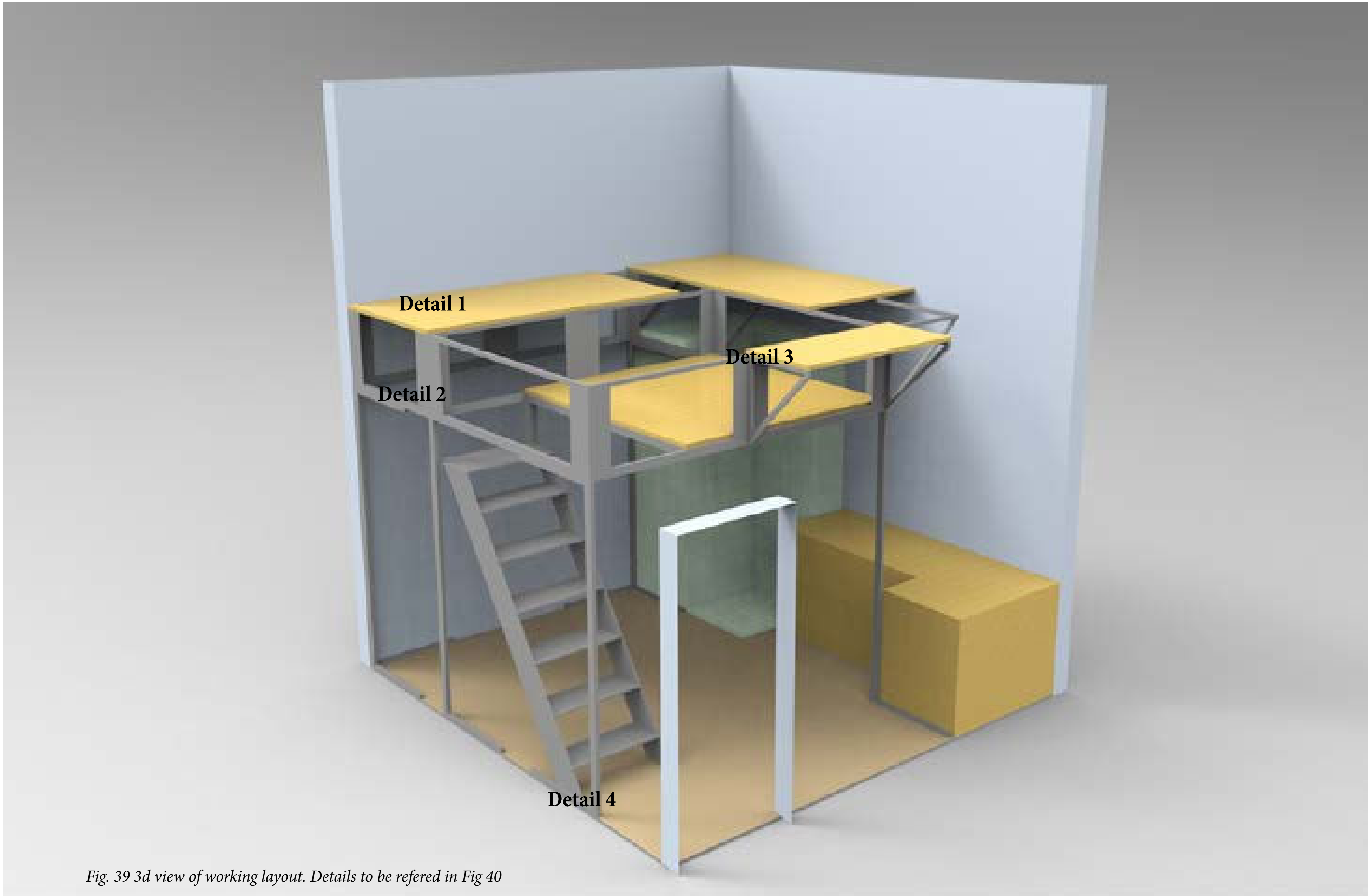


Fig. 39 3d view of working layout. Details to be refered in Fig 40

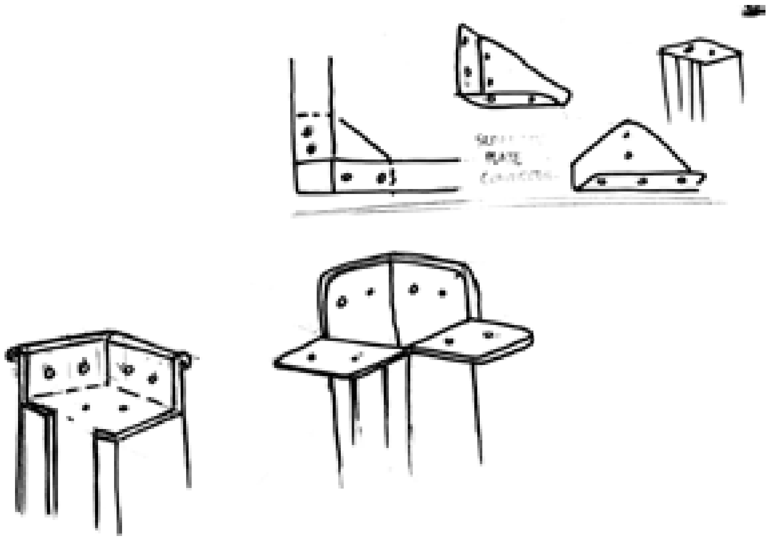


Fig. 40a Detail 2

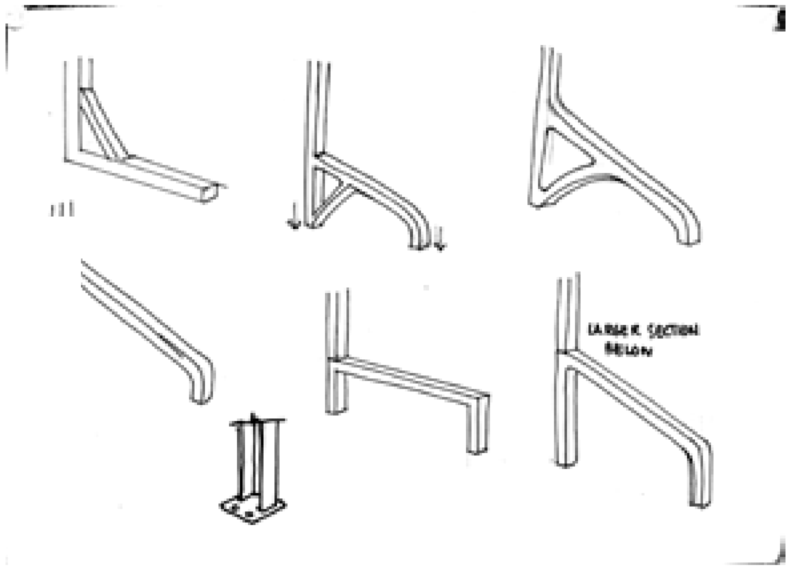


Fig. 40b detail 3

Fig. 40C Detail 2, corner detail of vertical support and gusset plate (left) and exten-
tion (right)

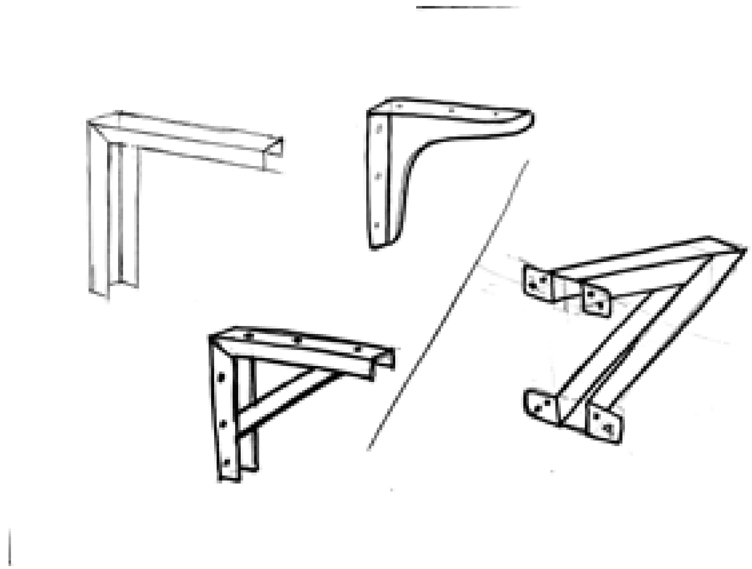
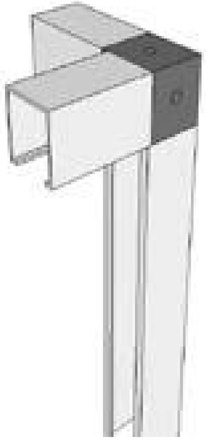
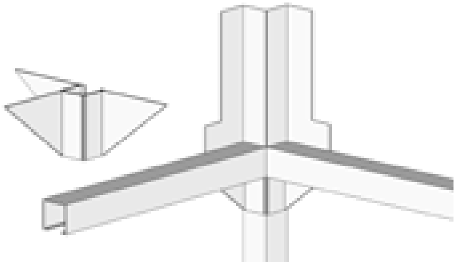


Fig. 40d detail 4

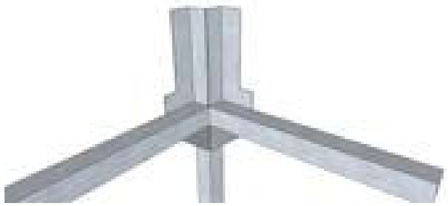
solid Stud used as fixure



After joining



Seoarate fixing unit with bracket

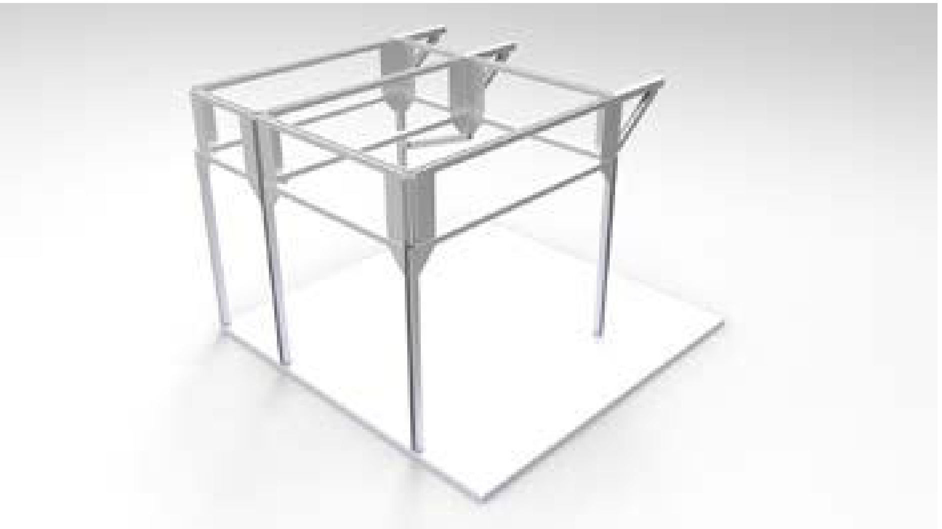


L joint after fixing

Fig. 41 Fixing details explorations

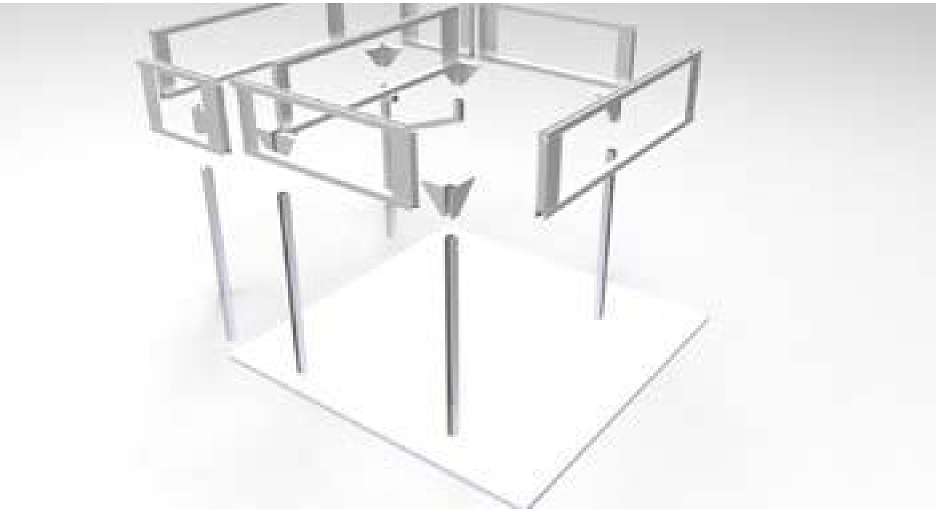
Final design evolution:

- The main aim of the joinery detail design was to achieve a system where it will be very easy for a person to assemble the components, structural stablity, aesthetics and extention of the structure without removing the old structure.
- it was thought of to separate the joinery detil from main components. This way, the structure could be standardised and fixing details can be replased or attached for future requirements.
- Concept of Lego blocks was used in the design development phase. Several options were thought of in the structural detailing and easy phase wise construction as well as making it aesthetical
- one of the proposed Solution was using of stud with threding on all side. This can work as a space frame connector and can grow the structure on any side.
- Second option was to have a separate unit of brackets. 2 types of brackets for L connection and T connection were developed. The problem with this design is that for T joint, ild L joint had to be removed and replaced.
- The requirement here was to develop a joinery where L joint can be converted into T joint without touching old assembly.



Frame structure

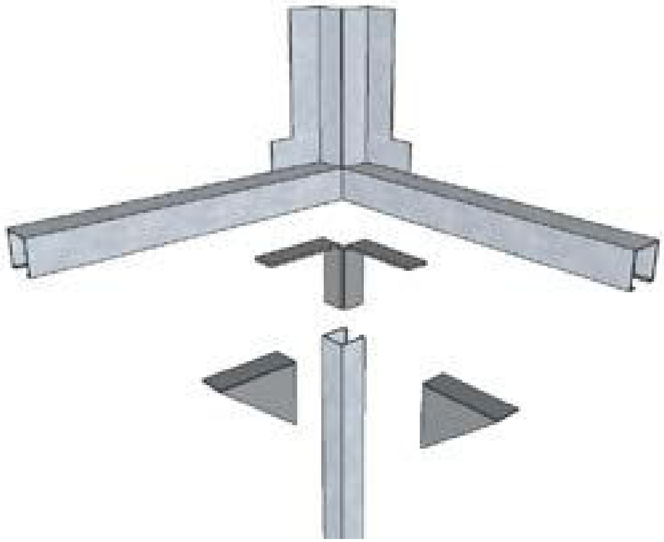
Structure



Exploded views

Fig. 42 Frame in fixing detail

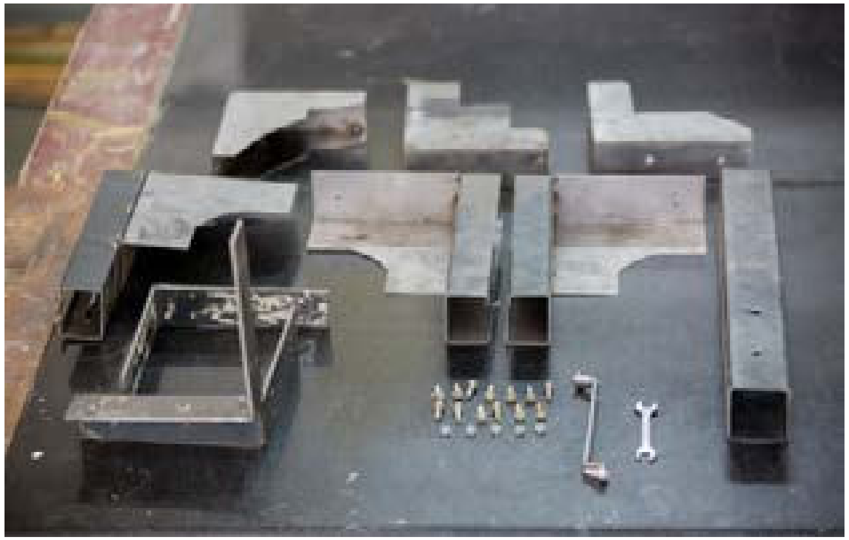
The Frame structure here works properly when we are having a structure of uniform frames and columns with varying fixing elements based on needs. Issues here are:
- The extention of L joint into T joint is difficult as the whole fixing element needs to be changed for that.
- For phase 1 structure, there are only 3 columns and the structure is highly unstable.
- The Brackets are too big and bolts are not hidden



exploded view

Assembly

Corner detail



Components

Fig. 43 Exploration of approach with taped flanges

Using Tapped Flanges and brackets:

- The detail was further modified into Flanges with Tapped holes which supported the frame on Columns.
- Here the need for replacing a L joint wuth T joint structur is eliminated and we can just add a flange to extend the structure
- Extra brackets are there for additional stability and aesthetical features
- actual scale prototype of a corner detail was made to check the ease of assembly and aesthetics.

it was realised that the structure looks too bulky and unappealing, hence the decision to eliminate the brackets and make the frames slimmer was taken.

Final design details:

- The Bracket is removed and the flang length is reduced.
- The beams are rotated so that the open side of closed C cross section faces towards wall and not down. This is done for aesthetical purpose but also provides many structural and assembly benefits.
- beams above the column where mezzanine floor panel is resting is made with a step in it for the plank to just sit on it. This will make the assembly and disassembly easy and faster.
- there are M10 bolts used at all the column frame fixing area for extra stability.
- At frame to frame joining, M5 bolts are used.
- The house develops in 4 phases and people buy what they can phase wise and drow the house.

First flrame for bed above and ladder

phase 1 finished

Phase 2 finished with platform

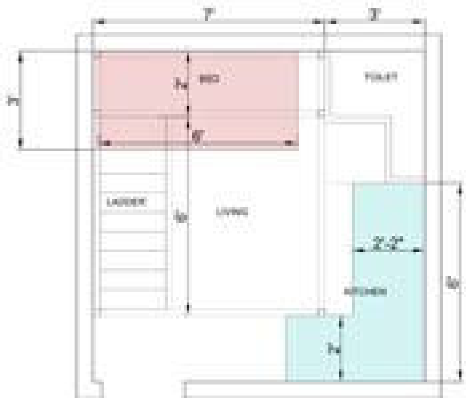
Phase 3 finished

Final phase finished

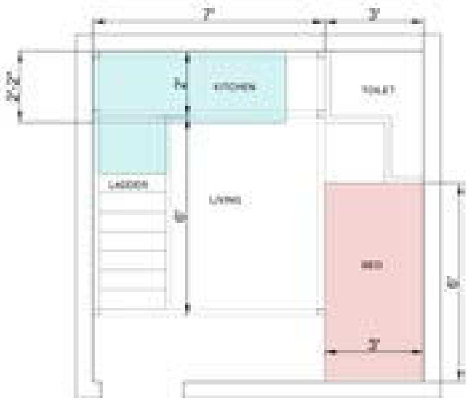
Fig. 44 Fixing details explorations

Layouts

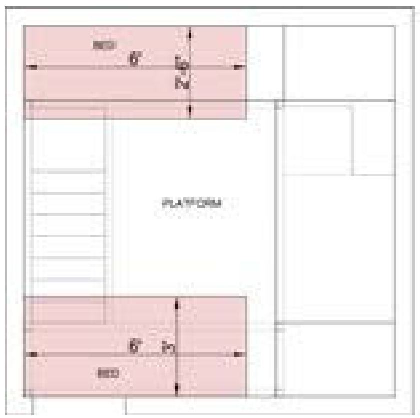
- There are 2 possible layouts in ground floor and 2 possible lay-outs in upper floor.
- by Mix and match, we will get 4 options available. The tenants can choose their layouts and with the same components its possible to creat all of them.



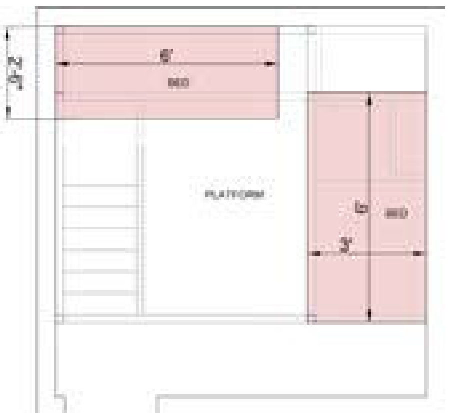
Layout 1 of Level 0



Layout 2 of Level 0



Layout 1 of Level 1



Layout 2 of Level 1

Fig. 45 Layouts possibility of assembly

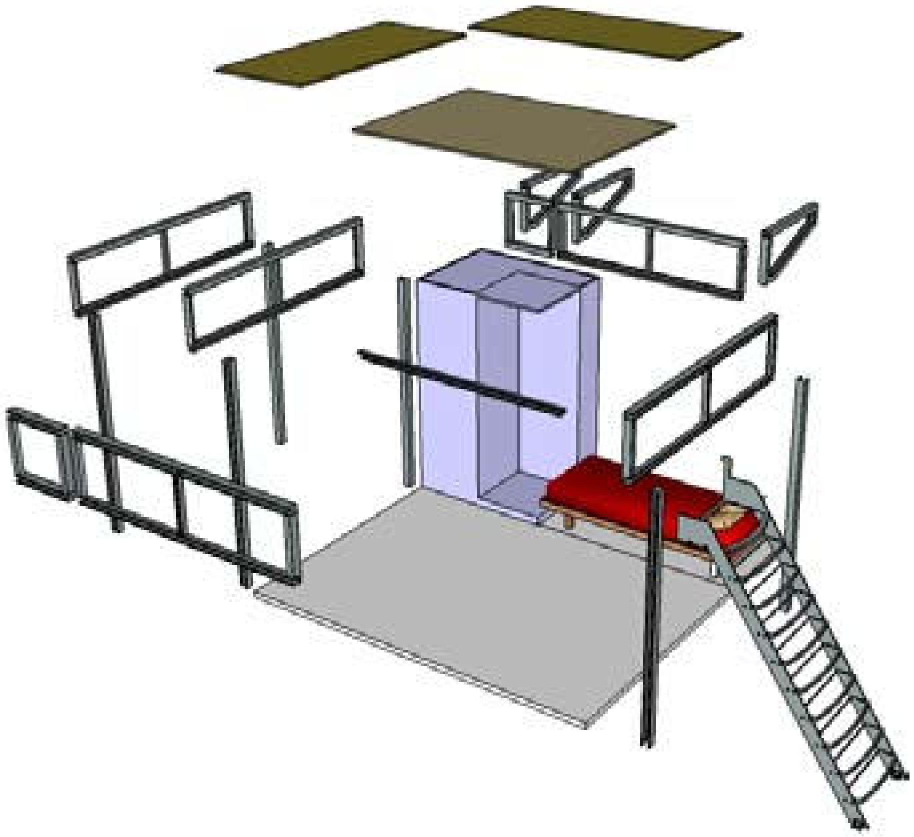
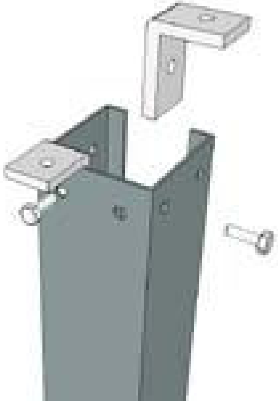


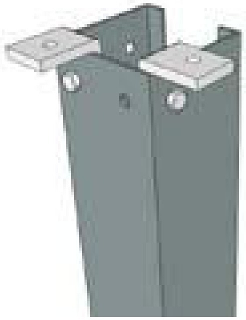
Fig. 46 Exploded view of structure showing assembly and components

Assembly guidelines and Details

- Fix flanges with M10 tapping in the holes on Base columns. There are identical holes on each sides of the column. Location where flanges are required has to be referred from drawing.
- Keep column lying on ground and fix the big frame on the flanges using M10 bolts.
- Side small frames to be fixed while lying on ground using M10 bolts
- Erect the structure and Fit the other 2 columns pre fit with the big frame. We get a structure for Bed.
- Secure all frames on top using Flanges and M5 bolts.
- Fix ladder to the structure and put bed panel on top of structure using Nut and bolts.
- For next stage, insert a flange to open sides of the 2 outer base columns and secure them with M10 bolts.
- Put a medium sized frame perpendicular to the large size frame and fix 5th column at the end of it bolting the frame on both its sides. Similarly, medium sized frame on other side to be secured.
- Now last large size frame to be fixed in between 5th and 6th column.
- Central runner to be fixed next to ladder using small flanges.
- Fix the floor panel using bolts.
- Put cantilever units on the side and bolt them using flanges.
- Bolt the bed panel on top. Basic structure is ready

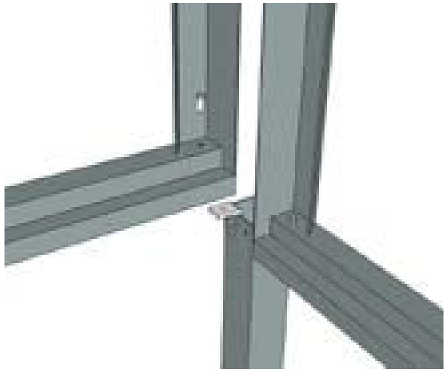


Connection of flange

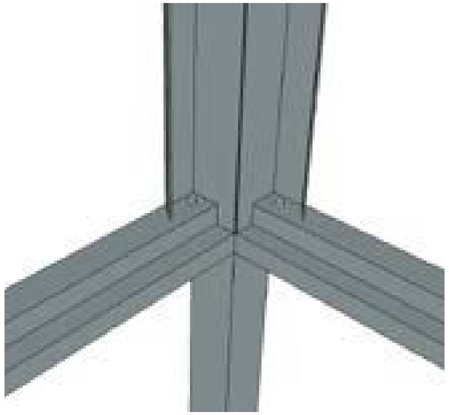


Holes depend on corner

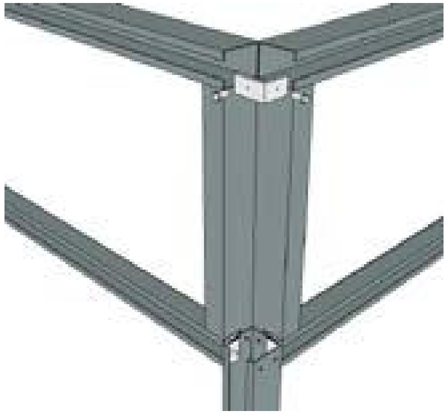
Frame put on top



Frames bolted



Corner detail



Flange on top

Central support

Central support fixed, notice step in beam for panel fixing

Fig. 47 Assembly details

Upper level

Upper level

Lower level

Area connecting Ladder and Platform. Ladder Upper step is bigger and act as landing

Fig. 48 Internal Views visualisation

external Views without wall

External views without walls

View of the structure with accssories

Fig. 48 Visualisation of structure with accessories

Fig. 48   Full scale Protyping

Fig. 48   Full scale Protyping

Fig. 49   Swaying in frame because of absence of tie in legs

Issues in design and solutions

The Prototype finally has an issue of swaying because the columns are 6.5'high and are not tied at bottom. Also there is no bracket on top hence there is some swaying movement.
This can be solved by:
- Providing 6"bracket at the corners
- Providing tie beams between each column
- Bolting the beams along wall with wall using flanges
- Wielding columns to a base plate and Grouting the base-plate to ground
- Providing tension wires along the sides

Fixing detail of Cantilever
The cantilever for bed is difficult to fix because the radius of MS flange used in Tying the previous structure is making it difficult for the cantilever structure.
This can be solved by:
- Redesigning of the cantilever structure by providing slits in it where ever there are structural requirements
- Resting the whole structure on the radius at lower level.

Packaging and phases

The Product can be developed in 4 phases. Customers can build the whole structure together if they can afford or grow it in phases.

Phase 1:
4columns + 2Big frames + 2 small frames + Ladder + Bed panel + Bolts + Tools
Phase 1 structure provides one extra bed structure at the upper level. Can be added to house when a child grows and needs privacy.

Phase 2:
2columns + 1Big frame + 2 Medium frames + flooring panel + Bolts + Tools
Phase 2 structure can be added when the child grows and needs its personal space for studying etc

Phase 3:
Cantilever pieces + Bed panel + bolts + tools
Phase 3 can be achieved when an extra bed is required at times when parents or relatives move in to the city from villages.

Phase 4:
Cupboard + study table + Booksheld + drawers
Once the person is able to afford extra furnitures, they can buy all these add ons and grow their house.

Marketing

The product can be introduced and marketed with various approaches keeping in Mind. The major 4 approaches proposed are:
Fitted with new buildings:

The furniture comes pre-fitted with an existing new development. The tenants just need to add all the extra accessories they need like cupboard and tables. Basic requirements come fitted.

Product selling Individually:
The components are sold in phases and assembled by the buyer in DIY. Assembly can be done by 2 people easily.

Existing Building retrofitting:
The product goes through some modification to fit into the existing buildings. This might require some cutting/wielding for which people can be trained.

Furniture system with box houses:
Furniture system on sale with mass manufactured steel box housing and whole unit develops incrementally.

Costing

The rough costing of final product is estimated based on discussions with the contractor and fabricator. The prototyping cost is high (more than 200% of the estimated product cost) because there were some changes/iterations and urgent CNC bending requirement.

Rough costing of project	For Prototyping	Actual Mass production cost
Pieces Bending and weilding	53000	23000
Bolts, Nuts, Vicer and accessories	900	500
MS pieces treatment and Painting	-	900
Panels	8000	2500
Miscellaneous	2000	1000
Total	**63900**	**27900**
Phase 1		
4 pieces platform column		5000
2 pieces long frame		4200
3 pieces small frame		2400
8 pieces 8mm L flange		500
Panels		900
bolts		300
Platform leveller		200
Total		**13500**
Phase 2		
2 pieces platform column		2500
1 pieces long frame		2100
2 pieces medium frame		4000
6 pieces 8mm L flange		500
Panels		1500
bolts		300
Platform leveller		200
Total		**11100**
Phase 3		
Cantilever parts		2000
Flanges		200
Bolts		200
Panels		900
Total		**3300**
		27900

Design Contribution:

- Worked on Layout of affordable housing, developing possible layouts from same components.
- developing a standard grid for furniture development.
- Efficient usage of space: space usage optimised
- Modularity in design incorporated
- Details for the DIY assembly explored and developed
- Sheet metal used instead of rolled section for easy assembly and manufacturing.

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