

Dharavi: An Inspiration for Live Work Architecture. An Analysis of the Recycling Industry in Dharavi and its Learnings

This paper provides an in-depth typo-morphological analysis of Dharavi's 13th Compound to expose the spatial specificity through which this socio-spatial ecology of living, working, and recycling is supported. It maps the process of recycling and patterns of inhabitation graphically, and analyses how the permeability of the urban tissue and the flexible definable thresholds between the inside and the outside engender and support the coexistence of living and production. The research has identified several typological and morphological concepts, such as a porous ground level, facilitating exchange and interaction; active roofs, which create social and workspace; a sectional stratification that allows both inhabitation but also material and production flows and progressive construction using recycled and scrap materials. The paper argues that these spatial concepts perform as a productive multi-scalar ecology of living and working from which lessons can be learned. These lessons can be adapted in the design to propose reuse, recycling, and live work as sustainable way forward in construction and architecture.

Keywords: Dharavi slum Mumbai, live / work architecture, recycling, sustainability, circular economy.

Key Literature Review

"I strongly believe that the west has much to learn from societies and places which, while sometimes poorer in material terms, are infinitely richer in how they live and organize themselves as communities."- King Charles III.

King Charles III, King of United Kingdom said this for Dharavi from his visit in 2003.¹ This paper builds upon this statement through in-depth research of the recycling, live - work industry of Dharavi and learns about the makeshift methods that make it successful. These lessons would be analysed and later adapted to the UK Industry.

The research methodology combines literature survey with a detailed typo-morphological graphic analysis.

Two reports, codeveloped by SPARC (Society for the Promotion of area resources centres), an NGO involved with urban poverty provided useful background information. The first, entitled "Reinterpreting, Reimagining and Redeveloping Dharavi", was a collaboration with KRVIA, an architecture college in India and analysed the Dharavi live world and its productive and economic contribution, as a basis for a proposal for the Dharavi Redevelopment project.²

¹Robert Booth, 'Charles Declares Mumbai Shanty Town Model for the World', *The Guardian*, 6 February 2009, section Art and design <<https://www.theguardian.com/artanddesign/2009/feb/06/prince-charles-slum-comments>> [accessed 1 January 2023].

²SPARC and KRVIA, *Re-Interpreting, Re-Imagining, Re-Developing Dharavi | Environment & Urbanization*, 2010 <<https://www.environmentandurbanization.org/re-interpreting-re-imagining-re-developing-dharavi>> [accessed 2 December 2022].

1 SPARC partnered with the University of Melbourne Architecture department
2 published a report in 2012, “Dharavi Informal Settlements and Slum Upgrading”. The
3 report focussed its research on the inhabitation of Dharavi’s settlements to develop
4 recommendations for upgrading and redevelopment. ³Research on the circular economy of
5 Dharavi provided a further data base of analysis. ⁴

6 This paper extends and contributes to the existing research by providing an in-depth
7 typo-morphological analysis of Dharavi’s 13th Compound to expose the spatial specificity
8 through which this socio-spatial ecology of living, working, and recycling is supported. It
9 maps the process of recycling and patterns of inhabitation graphically, and analyses how
10 the permeability of the urban tissue and the flexible definable thresholds between the
11 inside and the outside engender and support the coexistence of living and production.

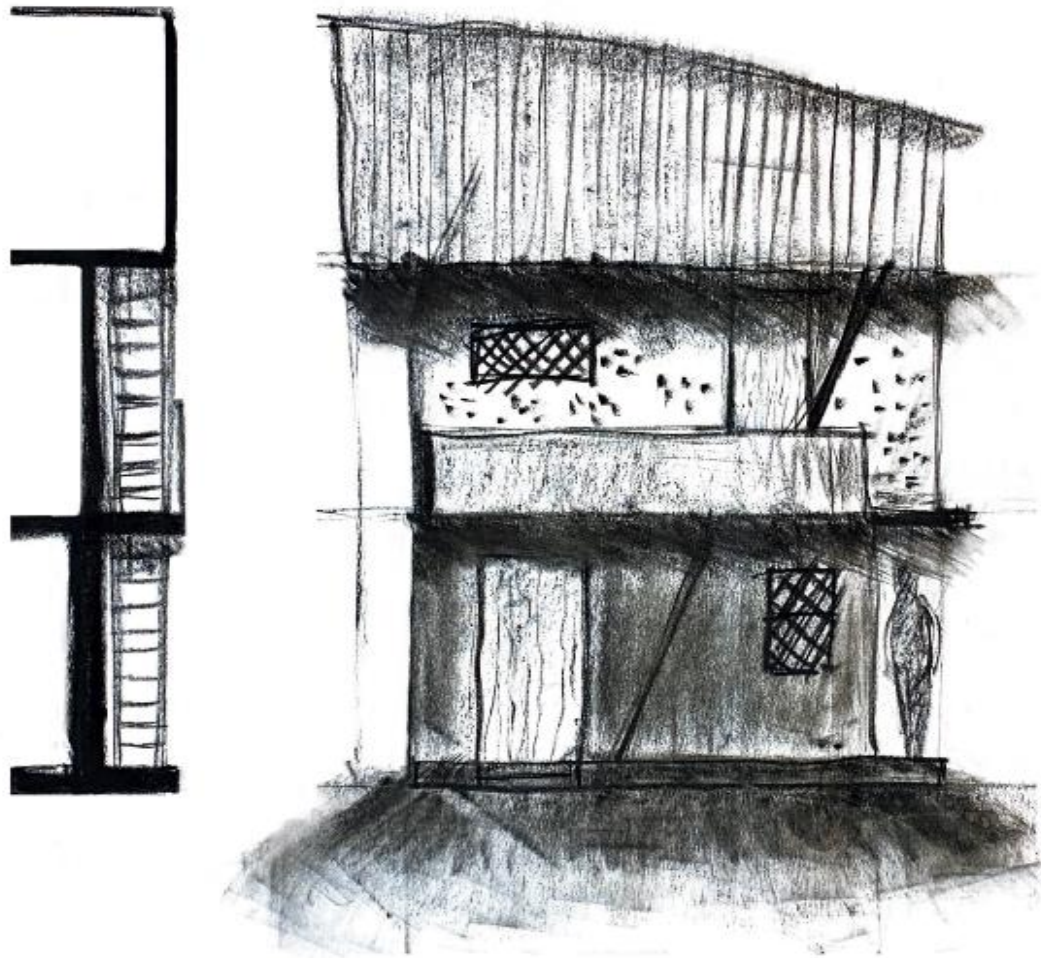
12 The research identified several typological and morphological concepts to show how
13 this support the multi-scalar ecology of living and working. It graphically analyses how
14 living and working, and an ingenious recycling process intersect. It also examines
15 progressive construction through reusing scarp and waste materials.

16 These themes are then concluded to be used as a sustainable approach in architecture
17 and construction.

³Kim Dovey and Richard Tomlinson, ‘Dharavi: Informal Settlement and Slum Upgrading’, 2012
<<https://minerva-access.unimelb.edu.au/items/bc0cfa30-e705-5bb8-802e-06a44e7dea26>> [accessed
13 January 2023].

⁴Sourav Dey, ‘The Circular Economy of Dharavi: Making Building Materials From Waste’,
PennState University Libraries, 2018 <<https://etda.libraries.psu.edu/catalog/15724szd62>> [accessed
12 January 2023].

1 **Figure A.** *Typical Dharavi Shanty*



Source: Author, 2023

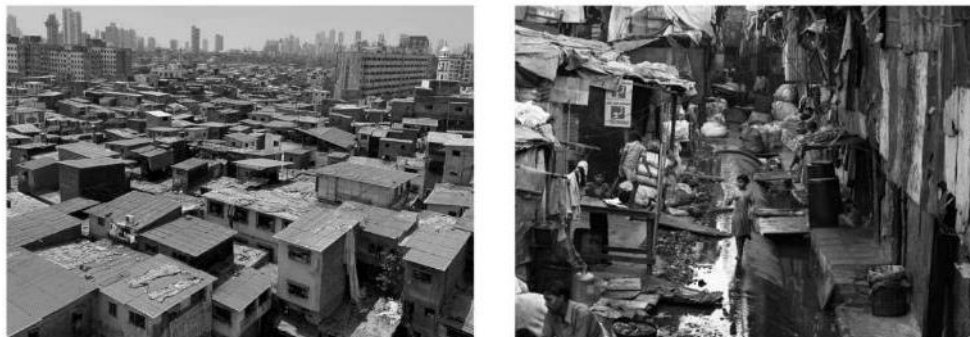
Dharavi Introduction

Dharavi an Urban Creative Cluster in the heart of Mumbai

Dharavi Slum is 525 acres of informal township in the heart of the metropolis of Mumbai in India. It is a city within a city - a maze of matchbox houses and shanties stacked together (Figure 1a) illegally to capitalize on whatever space is available for inhabitation. Negligence of the government has left Dharavi's hygiene and safety levels

grossly inadequate. Its unending dirty lanes, open sewers, and cramped huts (Figure 1b) exacerbate the effects of inadequate healthcare provision.⁵

Figure 1. (Left) *Maze of matchbox houses stacked over each other* & (Right) *Open sewers through the Dharavi Industry.*



Source: (Left) BBC, 2020; (Right) Chronicle, 2014.

Featured in the Oscar winning film *Slumdog Millionaire*,⁶ Dharavi is tagged as an infamous slum. “The film depicts a cliché of Indian squalor: dirt, overcrowding, and dangerous living conditions”.⁷ Bollywood film *Gully Boy*⁸ exploits the sensitive area of living in the slums very easily such as cramped houses, petty crimes, illegal drugs, domestic violence.

However, Dharavi’s informality and improvisation is a “response to the social ties and economic needs of the community”.⁹ It provides one million people with basic living and work and generates an informal annual economy of “one billion dollars”.¹⁰ The song ‘Mere Gully Mein’ from the movie *Gully Boy*,¹¹ vocalizes the purity, unity, hard work, and innocence in the life of Dharavi Slums even with the challenges it possesses.

History

Till the 19th Century Dharavi used to be a marshy wet land on the north most tip of Mumbai Island city and the home to the Koli Fishing community of Mumbai (Figure 2). Mahim Creek, north of Dharavi was their source of fish and livelihood.

The first people who migrated into Dharavi were artisans forced to relocate to set up micro scale industrial colonies in which they specialise. The growth of Dharavi was proportional to the migration of people in Mumbai (formerly known as Bombay). “People settled there “because the land, mainly used as an informal rubbish dump, was free and

⁵Carlin Carr, ‘The Best Idea to Redevelop Dharavi Slum? Scrap the Plans and Start Again’, *The Guardian*, 18 February 2015, section Cities <<https://www.theguardian.com/cities/2015/feb/18/best-ideas-redevelop-dharavi-slum-developers-india>> [accessed 2 December 2022].

⁶*Slumdog Millionaire*, dir. by Danny Boyle and Loveleen Tandan (Pathe Distribution, 2009).

⁷Lucile Guéguen, ‘India’s One-Billion-Dollar Slum’, *VOICES*, 2022 <<https://voiceskopje.org/2022/05/25/indias-one-billion-dollar-slum/>> [accessed 1 January 2023].

⁸*Gully Boy*, dir. by Zoya Akhtar (Zee Studio, Cinestaan, 2019).

⁹Carr.

¹⁰Jim Yardley, ‘Dharavi: Self-Created Special Economic Zone for the Poor’, *Deccan Herald*, 2012 <<https://www.deccanherald.com/content/216254/dharavi-self-created-special-economic.html>> [accessed 2 December 2022].

¹¹*Gully Boy*.

unregulated”.¹² Free space with the liberty to build illegally and without any regulations supported the cause of cheap accommodation for the migrants.

Figure 2. *Historical picture of Dharavi*

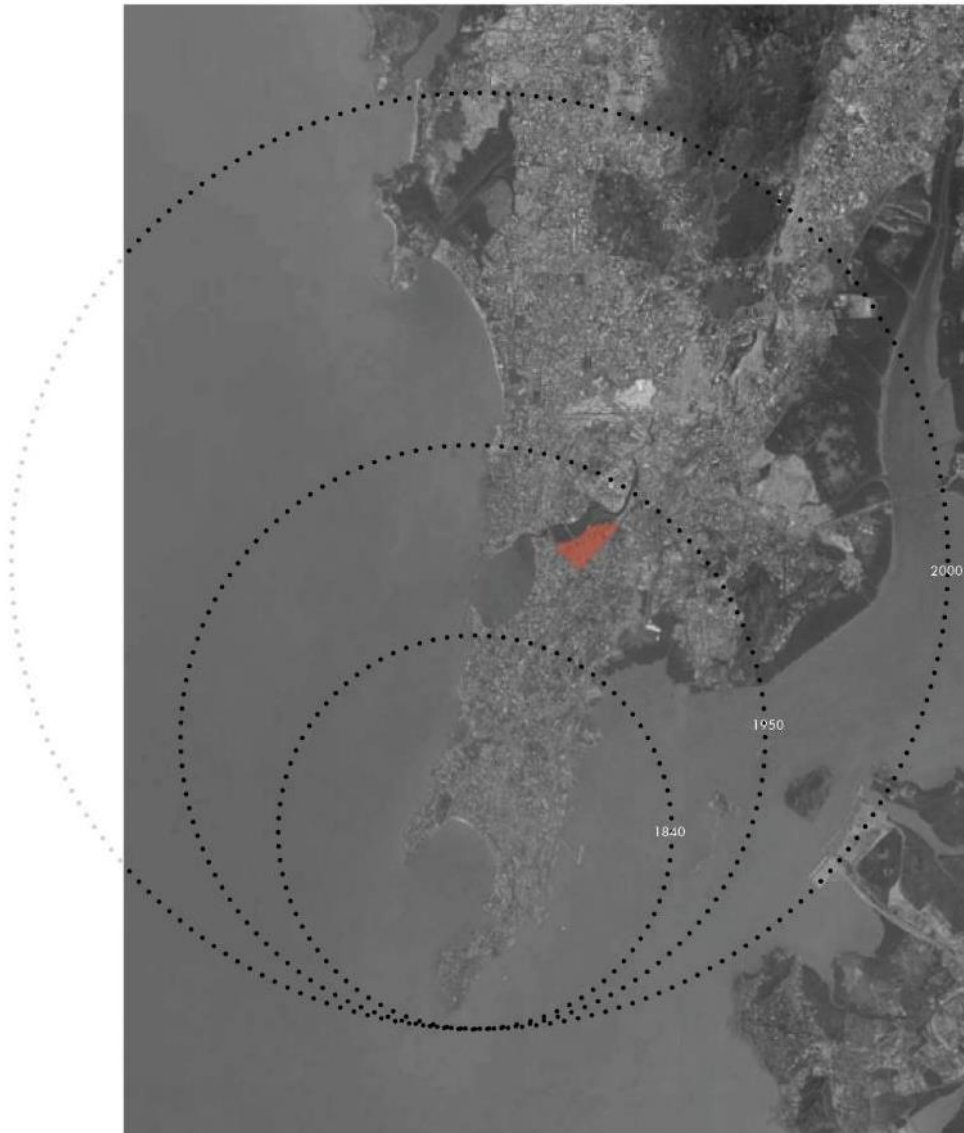


Source: Antiqua Print Gallery, 1849.

The activities of the squatters in the past did not affect the main city, but as this marshy land started to dry up and Mumbai started to expand northwards due to increase in population and industries, Dharavi was drawn into the heart of Mumbai. Figure 3 explains the growth of Mumbai Municipal limit and how Dharavi has become a centrally located prime location in the 21st Century.

¹² Mumbai SRA, ‘Growth History : Slum Rehabilitation Authority (SRA)’ <<https://sra.gov.in/page/innerpage/growth-history.php>> [accessed 14 December 2022].

1 **Figure 3.** *Mumbai historical urban edge of Dharavi's shift into the city.*



2 Source: The New Landscape by Correa, 1985, p.26 (Recreated by Author)

3 Mumbai Urban Edge ■ Dharavi

6 Location and Context

8 The illegal occupation of Dharavi by the squatters on this government owned land
 9 created a collection of slums built in a “haphazard manner”.¹³ Thus, in 1971 an act called
 10 the Maharashtra Slum Areas (Improvement, Clearance, and Redevelopment) Act was
 11 introduced. This was to improve the living conditions and hygiene levels of the slum.

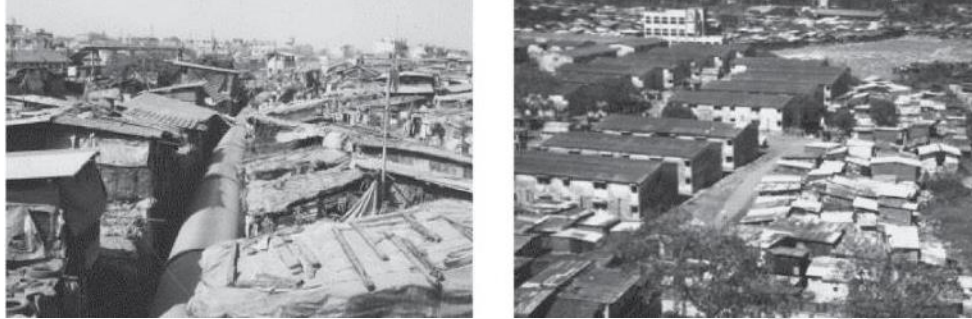
12 The Isolated triangular piece of land was connected to the main city, through the
 13 Sion-Mahim Link Road, the 60 feet and 90 feet roads (Figure 7, 9, 10). A census of
 14 hutments was carried out in 1976 and photo passes were issued to the slum families.
 15 People were provided with taps, toilets, and electrical connections. Open sewers and
 16 pipelines (Figure 6) were created for waste disposal. These developments (Figures 4)

¹³ SRA.

displaced people whose houses came in between, therefore transit camps were created to relocate them (Figures 1.6).

Figure 4. (Left) *Hutments removed to lay pipelines.*

Figure 5. (Right) *Concrete transit housing units.*



Source: (Left and Right) A review of slum housing policies in Mumbai, 1998
Photographer: G O'Hare

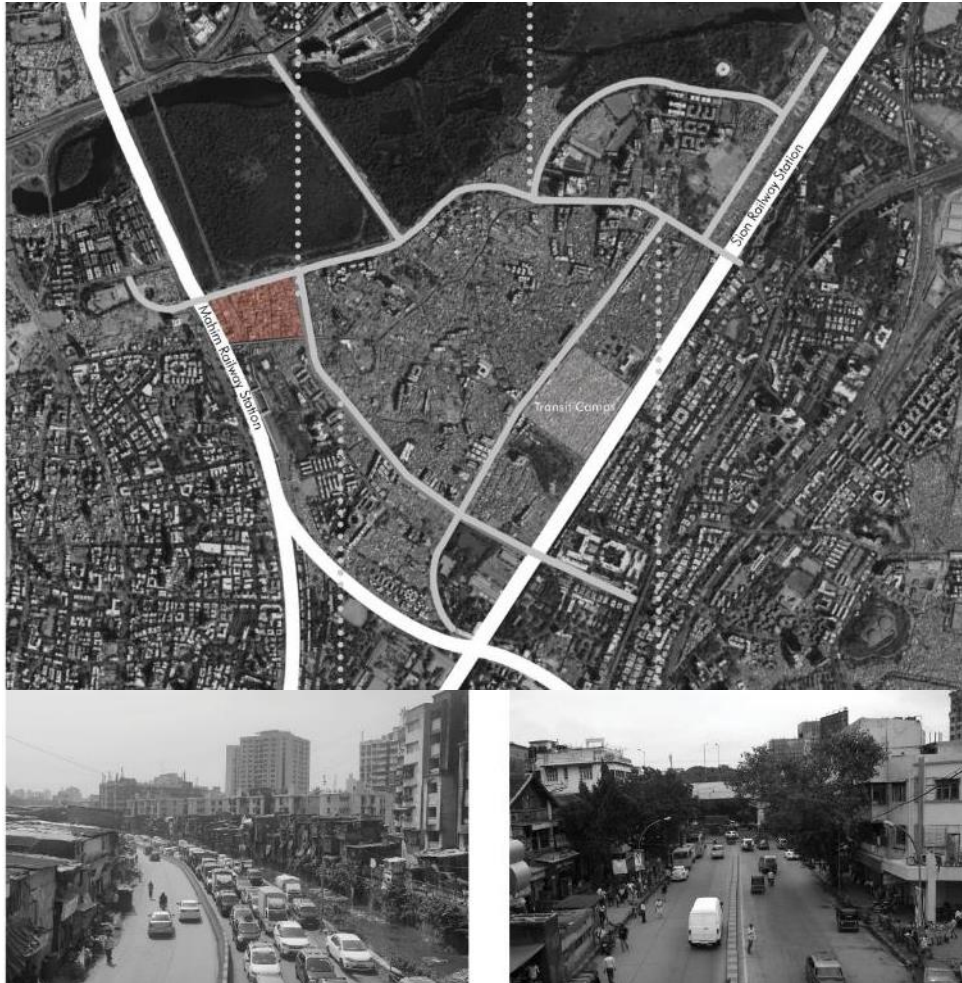
Mumbai is famous for “some of the world’s most expensive real estate transactions in the world”.¹⁴ With constant growth of the city today Dharavi has become a “goldmine” location.¹⁵ Mashian then states that the prices of the properties in Dharavi have skyrocketed, where shacks as small as 40 square feet command prices up to INR 10 lakh (GBP 10,000) on the market and the same sized shack can be rented for approximately INR 5,000 (GBP 50) per month. Today Dharavi is just a few kilometres south of the new business district of Mumbai - the Bandra - Kurla Complex. Famous landmarks like Gateway of India and Colaba are just south, and the Chhatrapati Shivaji Airport is less than eight kilometres away. Located on the intersection of two main train lines of Mumbai Dharavi is very well connected to the city (Figure 1.9). If Dharavi was to be cleared and revamped, it would be one of the most valuable real estates in the world.

Figure 6. (Top Left) *Open Sewers in Dharavi;* **Figure 7.** (Top Right) *Mahim – Sion Link Road;* **Figure 8.** (Middle) *Network of Dharavi;* **Figure 9.** (Bottom Left) *Dharavi’s 60 feet road;* **Figure 10.** (Bottom Right) *Dharavi’s 90 feet road*



¹⁴Sean Mashian, ‘Dharavi: When a Slum Becomes a Goldmine (6 Mins)’, *Cornell Real Estate Review*, 2018 <<https://blog.realestate.cornell.edu/2018/03/20/dharavi/>> [accessed 3 January 2023].

¹⁵Mashian.



Source: (Top Left) My India, 2014; (Top Right, Middle, Bottom Left) Google Earth, 2022; (Bottom Right) Lejagah, n.d.

13th Compound research site Atmosphere

Dharavi is busy every day, Carr¹⁶ mentions how it is noisy by 8am with tea stalls clinking, vegetable vendors ready to wrap up and plastic crushing machines cranking through the long day. This collage (Figure 11) portrays a typical day in Dharavi. It is like “being on a treadmill” and “everyone is busy”.¹⁷ It’s a city of enterprise that sells, produces, and manufactures everything.

¹⁶ Carr.

¹⁷ SPARC and KRVIA.

1 **Figure 11.** *Dharavi's Atmosphere*

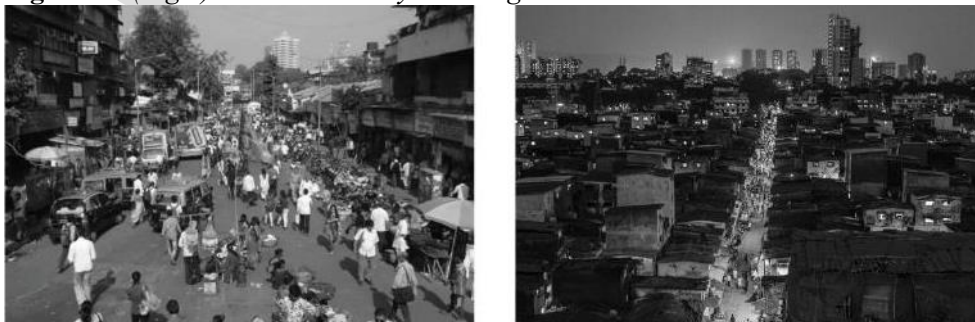


2
3 Source: Collage by Author
4

5 Dharavi always has traffic; it is always noisy and busy. Figure 12 shows hawkers
6 selling everything they can and an array of shops and restaurants behind them. The diverse
7 communities that work and function together in Dharavi showcase the guidelines of the
8 constitution of India - a secular and democratic country.
9

10 **Figure 12.** (Left) *Street Hawkers on main road*

11 **Figure 13.** (Right) *Dharavi is always working*



12 Source: (Left) Mulye, 2014; (Right) NY Times, 2020
13
14

Present Day

Today Dharavi seeks of hope for the low-income group people who migrate into the city (Figure 14). Patel¹⁸ mentions Dharavi to have “literally risen from the marshes” and how the poor have developed and reclaimed the land bit by bit. It is “a testament to the survival instincts of the poor – and the success of incremental development”.¹⁹ This migration led to the creation of families and neighbourhoods, which created a township for generations to live and work. Today these clusters are supposed to house “20,000 small-scale manufacturing units”²⁰ providing for the basic livelihood for millions. These clusters house micro scale industries specialising in recycling, pottery, leather tannery, embroidery, savouries, sweets, surgical thread, kites, gold and jewellery and printing.²¹ Dharavi, therefore, is a prime example of hosting creative clusters which successfully orchestrate the live/work culture. My research focuses on these topics through - The 13th Compound, Dharavi’s unique recycling industry.

Figure 14. Worker in the Plastic Recycling process (My India, 2014) IBID



Source: My India, 2014

The 13th Compound

The Informal Recycling Industry in Dharavi

The 13th Compound is Dharavi’s unique recycling industry. It is located on the Northwest Rim of Dharavi, on the junction of the two main roads - 60 Feet Road and Mahim - Sion Link Road (Figure 15). Even after living and working in hazardous and cramped conditions (Figure 16) the 13th Compound is successful in processing “approximately 80% of Mumbai’s hard domestic waste”.²²

¹⁸SPARC and KRVIA.

¹⁹SPARC and KRVIA.

²⁰Raina Assainar, ‘At the Heart of Dharavi Are 20,000 Mini-Factories’, *The Guardian*, 25 November 2014, section Cities <<https://www.theguardian.com/cities/2014/nov/25/dharavi-mumbai-mini-factories-slum>> [accessed 2 December 2022].

²¹SPARC and KRVIA.

²²Bath Spa University, ‘GtR’, 2020 <<https://gtr.ukri.org/projects?ref=AH%2FS005897%2F1>> [accessed 3 December 2022].

1 **Figure 15.** (Left) *The 13th compound location context*

2 **Figure 16.** (Right) *Densely packed homes*



4 *Source:* (Left) Author, 2022; (Right) My India, 2014

5
6 The 13th Compound Industry provides for the livelihood of “up to 250,000 rag-
7 pickers”²³ who gather rubbish all around Mumbai. “40,000 people are employed”²⁴ inside
8 the recycling micro-enterprises of 13th Compound. Heavy metal work and plastic
9 recycling make up most of the industries within this 8.34 acres of informal settlement.

10 Figure 17 represents the aerial view of the 13th Compound. Immediately the drawing
11 shows an impenetrable settlement with a few wide lanes and main roads which reflect the
12 routes which can be used to travel through the 13th Compound. This density of the 13th
13 Compound can be compared to Mumbai which is referred to as densest city in the world.²⁵

23 Bath Spa University.

24 Bath Spa University.

25 Elzy Kolb, ‘75,000 People per Square Mile? These Are the Most Densely Populated Cities in the World’, *WLST*, 2019 <<https://www.usatoday.com/story/news/world/2019/07/11/the-50-most-densely-populated-cities-in-the-world/39664259/>> [accessed 8 January 2023].

Figure 17. (Top) The 13th Compound Roof Plan

Figure 18. (Bottom) Dharavi Slum vs Mumbai City



Source: (Top) Author, 2022; (Bottom) Google Earth, 2022

Figure 18 shows how much more concentrated Dharavi is in comparison to Mumbai. However, 13th Compound is able to host the recycling industry as it is well connected with the Mahim Station on its West and three main roads on the other sides which has made it possible for the regular exchange of materials from and to Mumbai.

- 1 **Figure 19.** (Top) The 13th Compound Nolli Plan
2 **Figure 20.** (Bottom Right) The five sectors of recycling



Source: (Top and Bottom right) Author, 2023

The small, narrow lanes which disappear inside are what makes this exchange of materials and horizontal movement around possible (Figure 19). These lanes are so dense that they do not allow any light inside however create openings and access for the shanties inside.

The Sanaullah Recreational Ground is a cleared area of land by the government, which is now used as an informal space for keeping larger materials and storage for the industry. It is also used as an illegal camping site for the migrants.

The 13th Compound is a cluster of recycling industries set in five sectors - Paper Recycling, Tin Recycling, Goods Manufacturing, Plastic Recycling and Dye Manufacturing. These sectors create a system of initial sorting and structure which enhances the efficiency of the recycling process.

Figure 21. *Figure Ground Plan of the 13th Compound*



Source: Author, 2023

Key Spatial Principles

The wider lanes inside the 13th Compound are used for vehicular movement to allow for the material to be exchanged smoothly. It allows small trucks to enter the vicinity to drop off scrap to the recycling distributors and larger facilities (Figure 22, 24).

Figure 22. (Top Left) Dharavi Main Road; **Figure 23.** (Top Right) Water Logging in Dharavi; **Figure 24.** (Bottom Left) Wide Lane with vehicular access; **Figure 25.** (Bottom Right) Narrowest Lanes to create access.



Source: (Top Left) Network, 2020; (Top Right) Pathak, 2020 (Bottom Left & Right) Author, 2023

These materials are then transported further into the industry through people by accessing through the narrow lanes which connect the whole 13th compound together. They also work as breathing space for the houses on them. A key design aspect is that every house opens to a lane and all houses tend to have two narrow lanes to them. The use of these narrow lanes is key to the successful horizontal movement through the area (Figure 25).

Figure 26. (Left) Thresholds to minimise vertical access

Figure 27. (Right) Thresholds for storage and interaction



Source: (Left & Right) Author, 2023

To make the most use of space, the shanties cantilever three to four feet on free sides. This tends to create overhangs and increase space on the higher floors. Vertical access is generally through steel ladders outside the house to free up space and attain privacy. Proper steps to gain vertical access are created only when they purpose three to four settlements to gain most from. (Figure 26).

Raised Plinths are almost a must for every house front in Dharavi. Mumbai has a tropical and wet climate; therefore, these plinths act as a flood barrier to stop water entering the house (Figure 2.9). These have also been adapted in the design to host the first-floor staircase, add informal storage space to the house. It also creates a semiprivate space forcing people to walk further from the house. This design feature has acted as a key to facilitate interaction among the residents of Dharavi (Figure 27).

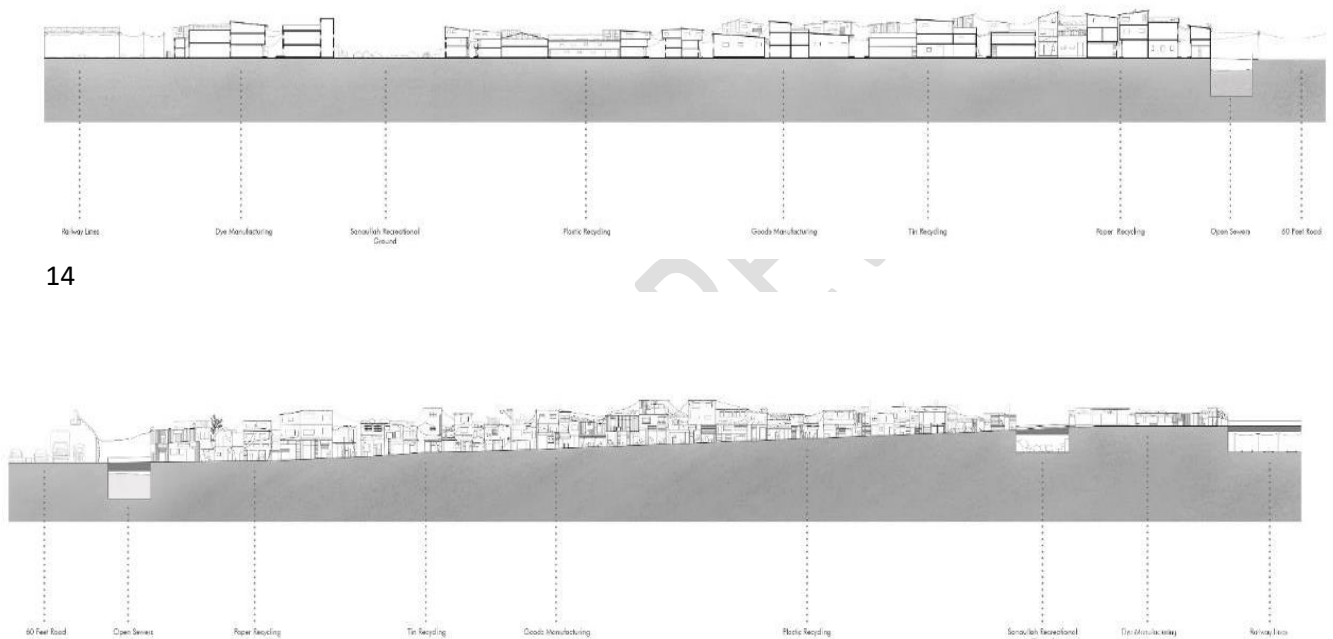
Section AA

Figure 28 shows the variation in sizes of the settlements. Working industries tend to be much larger than the housing facilities. However, it is a mix of live/work in every house. The figure depicts the density and creates a vision of how narrow the paths are for movement. Slanted corrugated asbestos sheet is a constant for all roof constructions to run off rainwater.

North Elevation

Figure 29 is the north elevation of the 13th compound. The informality in construction is really depicted here, however what is noticeable is construction through reuse. Scrap materials sourced through time are the main source of construction here. A high density of shops looks to have taken over the facade on the main road explaining that the industries are behind them. Even on the main roads the shanties have a height of less than 10m, which imply that they rarely build above three storeys. The slum seems to go down to one storey on the eastern region; however, it is the bridge which hides the other two storeys of those houses beneath it.

Figure 28. (Top) Section AA; Figure 29. (Bottom) North Elevation



Source: (Top & Bottom) Author, 2023

Key Social Principles

Dharavi is known to be a home to multiple occupations, religions, ethnicities, cultures that are integrated within the space of living and working.²⁶ The 13th Compound possess the same vibrant and diverse society hidden among the live work culture. The sense of its community is very strong, since all activities take place in the cramped and dense setting of Dharavi.

As mentioned before the Dharavi residents are migrants from all over India, hence the diversity of the community is very high. The main communities are - Hindu (60%), Muslim (33%), and Christian (6%) - each living in its own district, with temples, mosques,

²⁶UCL, 'UCL – University College London', *The Bartlett Development Planning Unit*, 2013 <<https://www.ucl.ac.uk/bartlett/development/files/contested-urbanism-dharavi>> [accessed 11 January 2023].

and churches.²⁷ The 13th Compound is a Muslim dominated district which can be identified with the dominance of three mosques in the area.

Even after being completely covered with the live work ethic, religious places can differ on how they are seen. Figures 30 and 31 show a formal place of worship, which stands out because of its architecture, construction, design, and dominance over the shanties. However, Figures 32 and 33 show an informal place of worship which blends with the settlements around it and can only be identified through its signage.

Being a Muslim District, people from all cultures are still intertwined within this place of living, working, worshipping, leisure, and socializing. Instincts of churches and Hindu temples being present in the 13th compound are clearly visible, and different communities stay together as this informality of space has created an overlap among the day-to-day cycle of existence.

Figure 30. (Left) Mosque in 13th Compound; **Figure 31.** (Right) Mosque in 13th Compound



Source: (Left & Right) Urbz, 2007

²⁷ACI, 'DHARAVI, INDIA'S MOST FAMOUS SLUM'.

1 **Figure 32. (Top) Moniya Jama Mosque; Figure 33. (Bottom) Zakaria Mosque**



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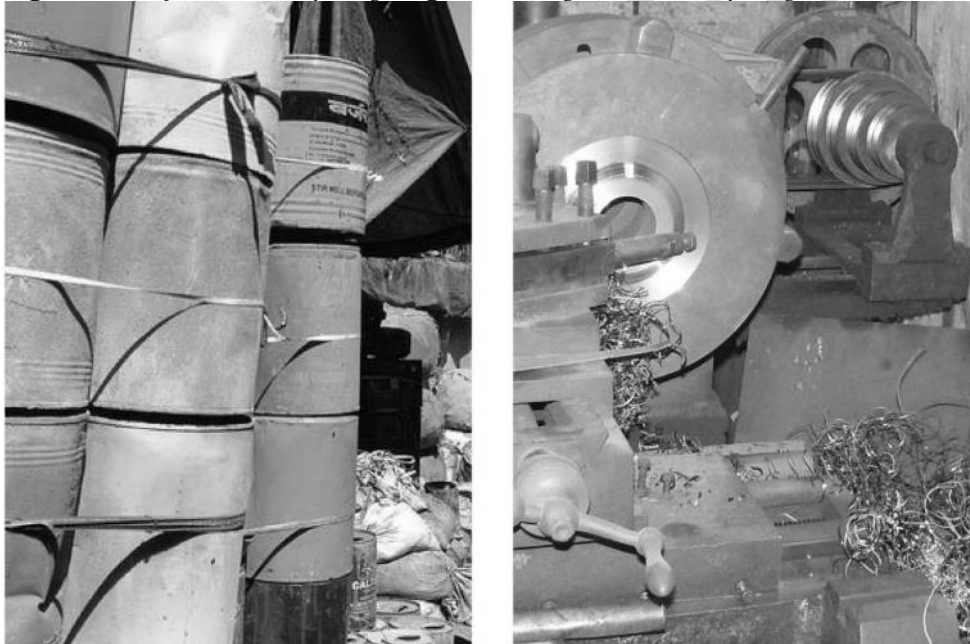
Source: (Top & Bottom) Author, 2023

Recycling Industries

In a study conducted by Pandey and Sharma²⁸, it was estimated that the 13th compound hosts 1200 waste recycling units, and out of these 780 units are part of the plastic recycling industry. 13th Compound is the largest recycling industry in India and is famous for recycling and reusing everything, “Oil cans, plastic drums, chemical drums, cotton scrap, iron scrap, empty tins, empty bottles and plastic drums, anything”.²⁹

The recycling industry in Dharavi is a way of reducing the carbon footprint of Dharavi’s polluting environment. From the Figures (33 - 38) it can be analysed that people sit in deep piles of waste sorting materials and grading them accordingly. Every minor item is recycled here. Lanes and paths are fully covered with recycling material - paper, cardboard, metal wires, aluminium tins, plastic bottles, plastic drums, plastic bags, glass, car batteries, computer parts, everything. Workshops have aluminium smelters that recycle drinking cans. Large Oil cans are reused by cleaning and hammered back into shape to be sold off to oil companies. The Scrap industry is also concentrated in the 13th Compound and cotton scrap, iron scrap, etc. are also recycled here. This industry, therefore, is part of the circular economy theme by reusing and recycling whatever waste is available to them.

Figure 33. (Left) Metal Recycling; Figure 34. (Right) Metal Recycling



Source: (Left & Right) Urbz, 2007

²⁸Nisha Pandey and Deepti Sharma, ‘Creating Synergy between Environment and Employment: A Case Study of Plastic Recycling Industry in Dharavi, Mumbai’, 1.4 (2015).

²⁹SPARC and KRVIA.

Figure 35. (Top Left) Paper Recycling; Figure 36. (Top Right) Paper Recycling; Figure 37. (Bottom Left) Glass Recycling; Figure 38. (Bottom Right) Glass Recycling



Source: (Top Left & Right; Bottom Left & Right) Urbz, 2007

Plastic Recycling

Largest Recycling Industry in the 13th Compound

The Plastic Recycling Industry (also known as Navrang Compound) is the largest industry in the 13th compound. This unregulated industry recycles 60% of Mumbai's

plastic waste compared to that of Singapore's 19% and alone provides employment and livelihood to 10,000 to 12,000 people.³⁰ Every day a minimum of 3,000 sacks of recycled plastic leaves the 13th compound, and whatever is not recycled is cleaned and repaired to be sold off second hand.³¹

Figure 39. (Left) Exterior; Figure 40. (Right) Interior



Source: (Left & Right) Urbz, 2007

Recycling Process

The initial step of the recycling process involves the rag pickers around the city of Mumbai whose job is to collect waste materials and deliver them to waste buyers around the city. (Step 1; Figure 43)

These are then delivered to the plastic industry through trucks and people using local transport. Once delivered to the main distributors in the plastic recycling industry, it is delivered to the micro scale plastic sorting industries inside the narrow lanes by people. (Step 2; Figure 43)

Piles of plastic waste are sorted by people in the tiny warehouses according to colour, density, and grade (resin identification code) (Figure 3.3). They have gained years of experience in the industry to perform this manual sorting, however a three-step process is involved: identification of the resin identification code; if not present match with a similar product, then immerse in a drum of salt water to help segregate. (Step 3; Figure 3.5)

Figure 41. (Left) Sorting of waste; Figure 42. (Right) Drying plastic fragments.



Source: (Left & Right) Materials of Hope, 2018

³⁰Trisha Mascarenhas A. geography nerd from NUS and others, 'Best Sustainable Gifts in Asia - Green Is The New Black', 2018 <<https://www.greenisthenewblack.com/dharavi-asias-largest-slum-indias-recycling-circular-economy-goldmine/>> [accessed 11 January 2023].

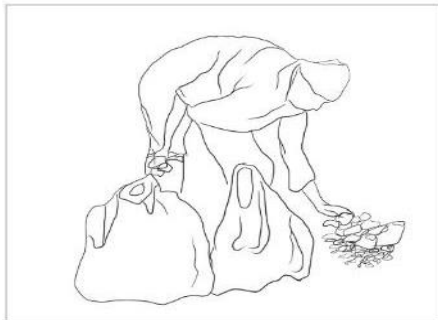
³¹SPARC and KRVIA.

After the separation of materials, they are shredded in the plastic crushing units. Metal machinery made of scrap waste metal is used to crush bigger pieces of plastic into micro plastics. (Step 4; Figure 43)

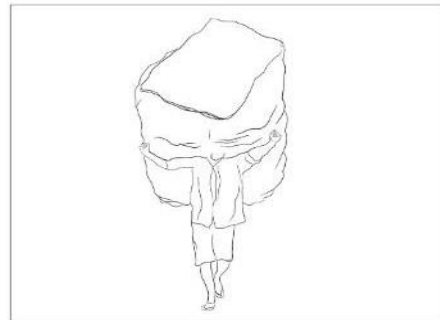
The tiny plastic pieces they are thoroughly cleaned and washed in the large blue plastic drums to get rid of any waste or toxins. Plastic fragments are then filtered using plastic colanders and filled in bags. (Step 5; Figure 43)

These wet plastic shreds are then spread out in open space, generally roofs (Figure 42) and open ground to dry (Step 6; Figure 43) after which they are sold off to melting facilities over India to be reused. Due to health regulations Dharavi does not have any melting facilities.

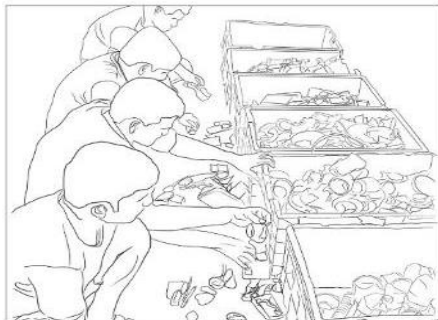
Figure 43. *The recycling process storyboard*



Step 1. Rag picking



Step 2. Delivering



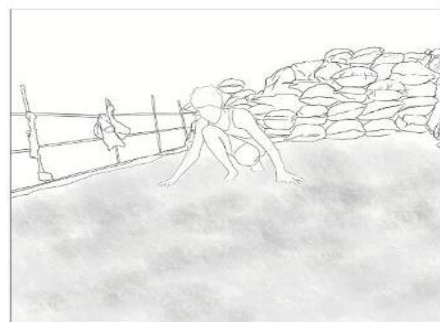
Step 3. Plastic Sorting



Step 4. Pulverizing



Step 5. Washing



Step 6. Drying

Source: Author, 2023, *Recycling process video* courtesy: *Materials of Hope*
<https://vimeo.com/277435980>

1 **Figure 44.** *Plastic Recycling Industry North Elevation*



2 Source: Author, 2023

3 4 5 **Design Principles**

6
7 Foster and Partners³², a UK based architecture firm's design team conducted a study
8 of Dharavi in 2008 for the redevelopment of Dharavi. The scheme illustrated the idea of
9 mixed-use buildings hosting small commercial premises, industrial units and housing.
10 Another key observation, from the drawing was commercial and light industries (Figure
11 45) are present on the main roads and outer rims of the industry whereas high density live
12 work industries thrive behind them (Figure 46). Figure 44 illustrates the idea of a
13 commercial main road, and Figure 47 supports the case by showing the dominance of
14 commercial units on the Northern edge of the side. Commercial units are present on the
15 ground because of the dominance of work in the cluster and as a design principle to allow
16 easy exchange of goods and interaction among the working community. Living sectors are
17 much smaller and inside narrower lanes. Figures 48 expands on the mixed-use
18 observations and cut through the dwellings to denote the recycling industries and living
19 industries in comparison to one another.

20
21 **Figure 45.** *(Left) Shops on main street; Figure 46. (Right) Dense live / work areas*



22
23 Source: (Left) Google Earth, 2022; (Right) Urbz, 2007

24
³²Foster + Partners, 'Dharavi Masterplan | Foster + Partners', 2008 <<https://www.fosterandpartners.com/projects/dharavi-masterplan/>> [accessed 15 January 2023].

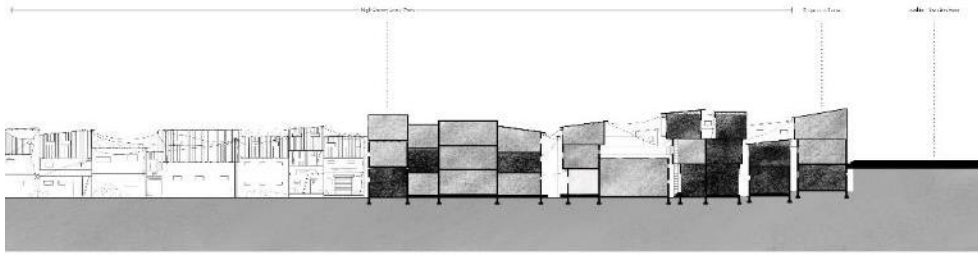
1 **Figure 47.** *Plastic Recycling Industry Plan*



2
3 Source: Author, 2023

4
5  *Living*  *Working*  *Institutional*

1 **Figure 48.** *Section BB cutting through the plastic recycling industry*



2
3 *Source:* Author, 2023

4
5 **Figure 49.** *(Top Left) Plastic bags;* **Figure 50.** *(Top Right) Plastic paint cans;* **Figure 51.**
6 *(Bottom Left) Plastic drums;* **Figure 52.** *(Bottom Right) Plastic recycling process*



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26 *Source:* (Top Left & Right) Urbz, 2007; (Bottom Left & Right) Urbz, 2007

27 28 29 **Inhabitation**

30 31 **Live/Work Recycling Industry**

32
33 The 13th Compound integrates the concept of live / work architecture in the
34 recycling industry. It teaches us “how the informal settlements generate solutions for the
35 demands of small businesses and housing”.³³ Flexibility in the work schedule, reduced
36 travel time, home based occupations, work in various scales for everyone, connection with
37 the community, and use of local products – these are the ways of “how the poor not only
38 survive but thrive without handouts or charity”.³⁴

³³SPARC and KRVIA.

³⁴SPARC and KRVIA.

Figure 53. *(Left) Living inhabitation (Kitchen Space)*

Figure 54. *(Right) Working inhabitation (Storage Space)*



Source: (Left) Gully Boy, 2019; (Right) Urbz, 2007

Inhabitation

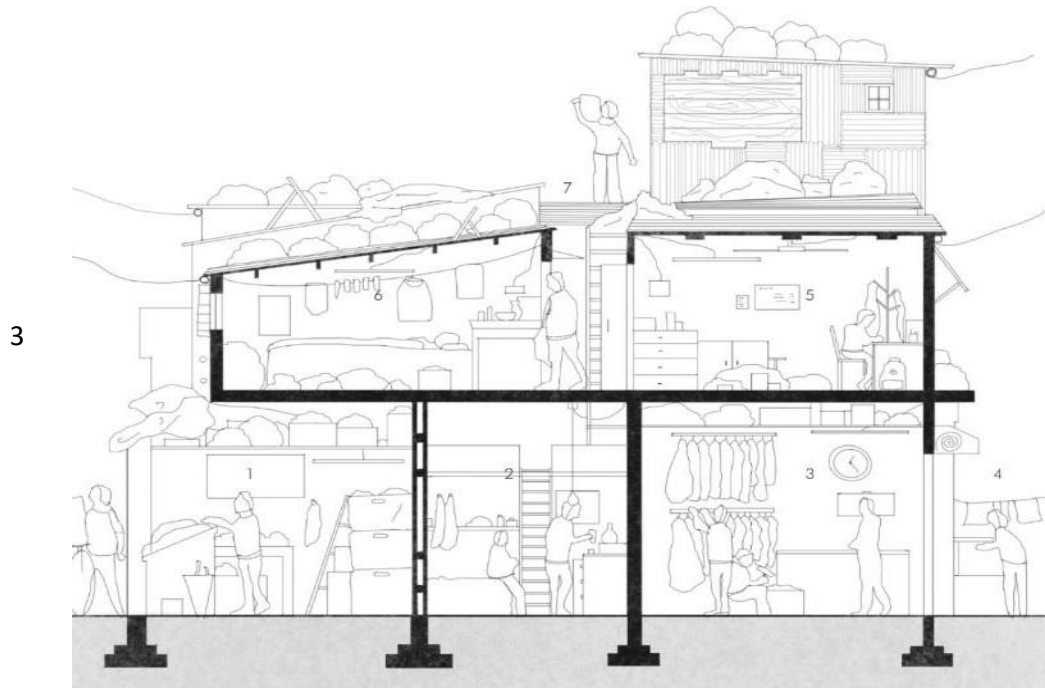
Inhabitation in Dharavi means to utilise every square foot of ground they own. Live/Work scheme is adapted to the houses (Figure 4.6), meaning living and working under the same roof or same vicinity.

Figure 55. *(Left) Manufacturing;* **Figure 56.** *(Right) Studio like living*



Source: (Left) Gully Boy, 2019; (Right) Urbz, 2007

1 **Figure 57. Inhabitation Drawing:** 1. Laundry; 2. Living – six people; 3. Dyeing Industry;
 2 4. Outdoor Dyeing Area; 5. Embroidery + living; 6. Living; 7. Active Roofs

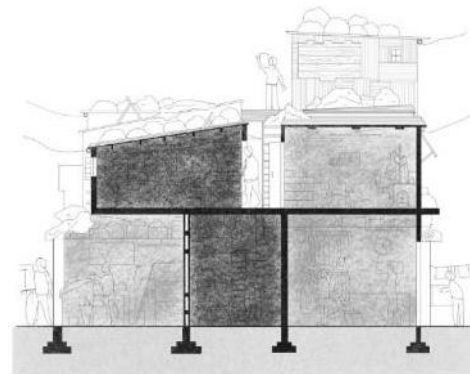


4 Source: Author, 2023

5
 6 Figure 57 shows an accurate example of dense living, where five people inhabit a
 7 room of 85 square foot.³⁵ Mezzanines and lofts are created in the vertical spaces to
 8 generate sleeping and storage area.

9 Workplaces are more informal and open plan and adapt as to the need of the
 10 industries. These tend to be bigger compared to the living accommodations as the
 11 dweller's livelihood is dependent on working and priority is given to that. Some migrants
 12 do not have living areas therefore, they live and work in the same place.

13
 14 **Figure 58. Live Work Diagram**



16 Source: Author, 2023

17
³⁵Dovey and Tomlinson.

1 **Figure 59.** *Living Model with Loft (Dharavi Shanty 1:20 physical model)*



2
3 Source: Author, 2023
4

5 **Living**

7 Figure 59 shows a typical model of accommodation with mezzanine in the 13th
8 Compound. This living space is around 150 square feet and accommodates seven people.
9 One thing which is very noteworthy is that even after being cramped into a small space,
10 the house has everything the dwellers require through the day. It is well decorated and
11 personalised with the residents emotional and materialistic values.³⁶

12 During the day the men of the house leave for work early in the morning and are
13 back for dinner. This allows the women to do household works, cook in the kitchen and
14 look after their children. Sometimes women have small home businesses like tiffin
15 services, sweets, and savouries production just to generate some extra income.

16 During the night is when everyone is at home, and to accommodate everyone, adults
17 take the beds, and children and youngsters sleep on the floor and mezzanine over a carpet
18 or rags. As shown in Figure 60, the house is very densely packed with storage under the
19 bed and study table, over the cabinets and on the mezzanine floors.
20

³⁶Dovey and Tomlinson.

1 **Figure 60.** *Living with loft interior vignette model*



2
3 *Source:* Author. 2023

1 **Figure 61.** *Plastic Recycling Model (Dharavi Shanty 1:20 physical model)*



2
3 Source: Author, 2023

4 5 **Plastic Recycling Industry**

7 Figure 61 shows the typical layout of a plastic sorting industry. Crates are used as a
8 part of sorting mechanism. A corner is fixed for the rags of plastic waste to be dumped,
9 and adequate amount is brought to be sorted and sent to the crushing units. Resting places
10 inside are present for the employees to take rest because of the long eleven-hour shifts.³⁷
11 Sometimes the migrant workers live inside the rooms they work and generally use street
12 vendors for food.³⁸

13 Figure 62 shows the interior which looks to be very well illuminated with tube lights
14 in the working areas and decrease around the room. Plastic sorting is the focus, and no
15 other facility is present in here. Clothes hang around the walls as the workers change into
16 different clothes so that the regular clothes stay clean. Fans are not seen, which suggests
17 that they generally work in very humid and hot conditions.
18
19

³⁷SPARC and KRVIA.

³⁸Dovey and Tomlinson.

1 **Figure 61.** *Plastic recycling sorting interior vignette model*



2
3 *Source:* Author. 2023

1 **Figure 62.** *Commercial Enterprise Model (Dharavi Shanty 1:20 physical model)*



2
3 *Source:* Author, 2023
4

5 **Commercial Working Space**

6
7 Apart from the recycling industry the 13th compound also hosts other commercial
8 spaces such as offices, restaurants, hotels, and grocery stores. Figure 62 shows an 100
9 square feet of space partitioned from the storage space, to be used as small office with 5-6
10 employees.

11 These units adapt to the scheme of an open plan, which is inhabited as per need of
12 the user. The office spaces are generally present on the topmost floor of a shanty as the
13 priority is given to recycling and living in the 13th compound.

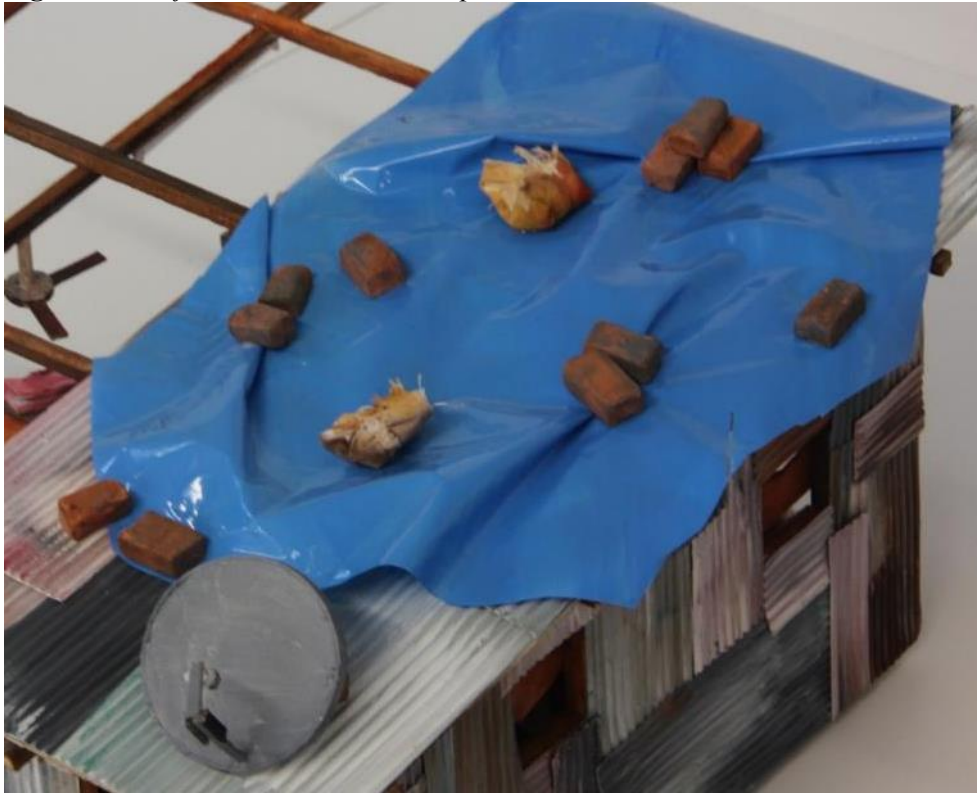
14 The offices have tube lights and have fans for ventilation. Electricity is pulled in from
15 the streets. Piles of papers, files and folders lie open on the tables and racks. Stacks of
16 paperwork lie around on the floor. Lightweight pavilion like construction is visible from
17 the interiors because of the makeshift construction technique.
18
19

1 **Figure 63.** *Commercial office interior vignette model*



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Source: Author. 2023

1 **Figure 64. Roof structure model with tarpaulin sheet**



2
3 Source: Author, 2023
4

5 **Active Roof**

6 The roofs of the shanties (Figure 64) provide the people of Dharavi with a sense
7 of openness which is lost in the cramped and dense atmosphere of the ground level. The
8 Recycling industry hosts a unique solution of utilising and inhabiting roof space. It is used
9 as an informal storage dump and used as a drying area for the recycling industry (Figure
10 65 and 66). Some migrants use it as an extremely makeshift live workspace (Figure 67).
11 Children and youngsters consider it there socialising and resting area (Figure 68).
12

13 **Figure 65. (Left) Recycling on roof; Figure 65. (Right) Roof Storage**

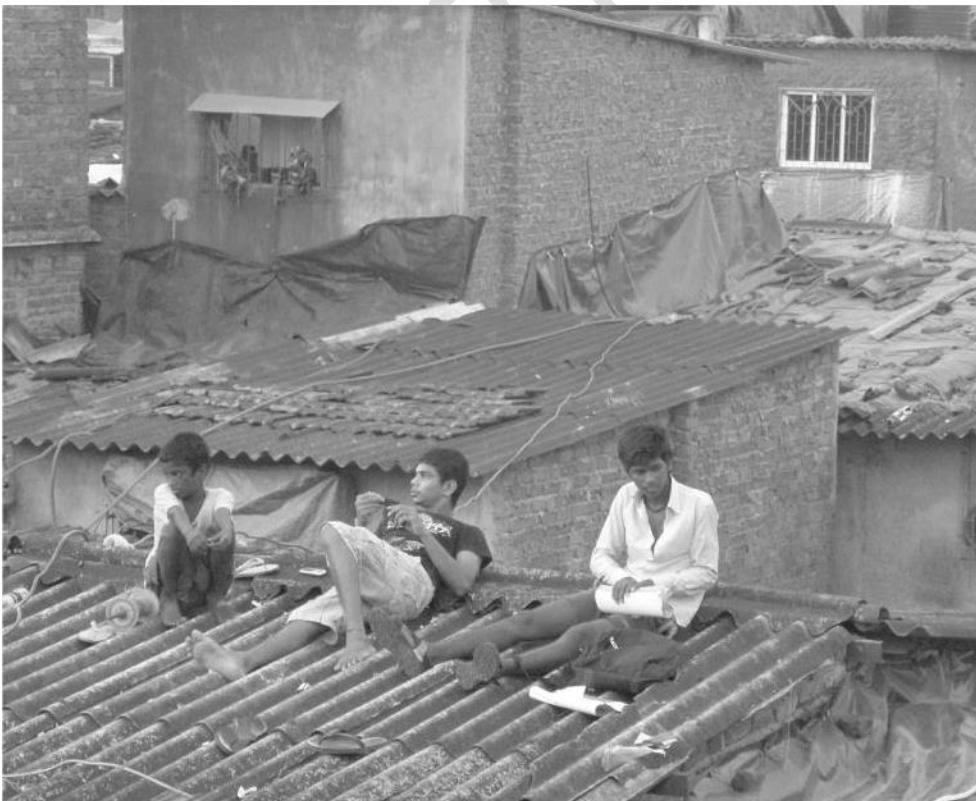


14
15 Source: (Left) RICS, 2021; (Right) Uncornered market, 2007

1 **Figure 65.** (Top) Informal work industry on roof; **Figure 66.** (Bottom) Social and Leisure
2 activities on roof



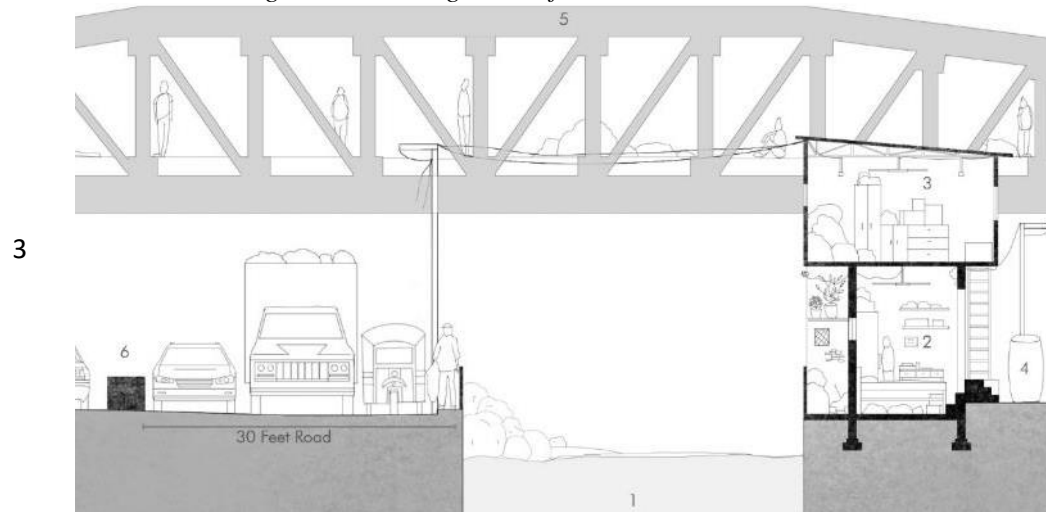
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6 *Source:* (Top) Urbz, 2007; (Bottom) Urbz, 2010

Figure 67. 60 Feet Road Inhabitation 1. Open Sewer; 2. Living; 3. Storage and working; 4. Outdoor Storage; 5. Foot Bridge; 6. 60 feet road

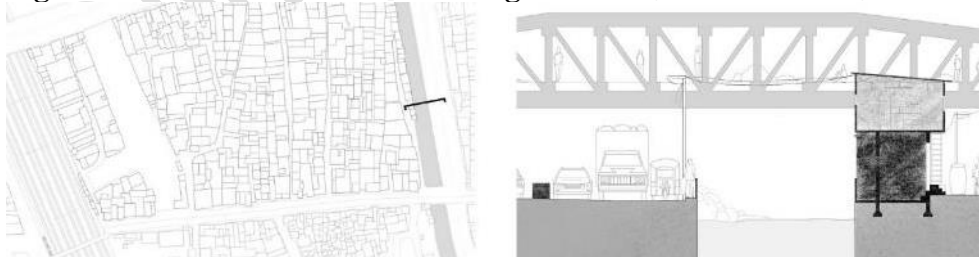


Source: Author, 2023

60 Feet Road

The 60 Feet Road is a six-lane main road which allows trucks and lorries to travel through Dharavi (Figure 70). Part of the development in the Slum Rehabilitation act, the 60 feet road connects the community to the larger city. This enabled the vehicular material exchange of waste between the 13th compound and Mumbai's waste distributors and buyers, an integral source for the recycling industry. The footbridge over the road connects the 13th Compound and Dharavi to Mahim Railway Station. This acts as an integral connection for the Rag pickers who sometimes deliver material directly to buyers in Dharavi. Using local trains are more economical and time saving and serves as a great link with the city. Open Sewers are another infrastructural development part of the Slum Rehabilitation Act, this disconnects the 13th Compound from the main road and is currently used for the waste disposal of the Dharavi (Figure 67). Live work settlements are built at the edge of the open sewers even after being polluted with industrial waste and insoluble plastics (Figure 69).

Figure 68. (Left) Location in compound; Figure 69. (Right) Live work diagram



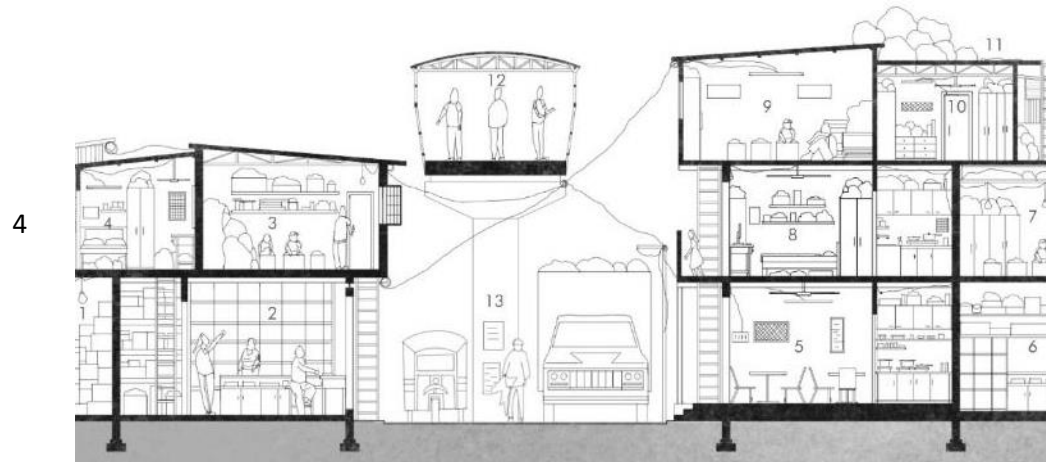
Source: Author, 2023

1 **Figure 70.** *60 Feet Road*



2
3 *Source:* Google Earth, 2019; Photographer Suman Kumar

Figure 71. Dharavi Main Road Inhabitation 1. Storage; 2. Living; 3. Recycling Industry; 4. Grocery Store; 5. Restaurant; 6. Grocery Store; 7. Recycling Industry; 8. Living; 9. Recycling Industry; 10. Living; 11. Active roof; 12. Foot bridge; 13. Main Road (7 metres)

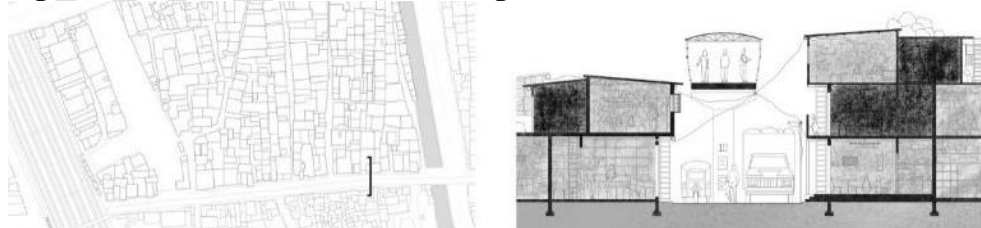


Source: Author, 2023

Dharavi Main Road

The Dharavi Main Road ranges from 6 metres to 8 metres wide because of the irregular shape of the road created due to the slum housing.³⁹ This provides vehicular access to the south of the 13th compound and allows trucks to reach drop off and pick up points inside the 13th compound. What's interesting about the main roads are that they tend to hide the living and working industries behind them. They are lined up with two to three storey houses with shops, restaurants, hotels, commercial bodies, and institutional places on the ground floor, similar to high street in cities (Figure 71). It is noisy with vehicles stuck in the dense pedestrian traffic. Vendors, shops, and tea stalls open up onto the roads decreasing road space in an already tightly packed street. Social spaces and pedestrian retreat points on the edges of the Dharavi Main Road are particularly valuable.⁴⁰ Figure 73 shows, how the working industries dominate the main streets as compared to living. The use of roofs for storage, work and socialising is very important here.

Figure 72. (Left) Location in compound; **Figure 73.** (Right) Live work diagram



Source: Author, 2023

³⁹Dovey and Tomlinson.

⁴⁰Dovey and Tomlinson.

1

Figure 74. *Dharavi Main Road*

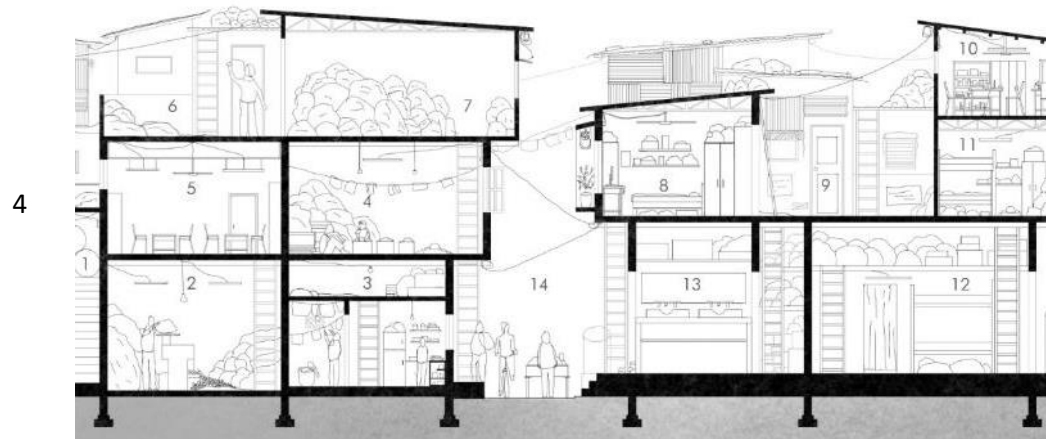


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Source: Toothpicker, 2019

1 **Figure 75.** *Narrow Streets Inhabitation* 1. Drum Manufacturing; 2. Plastic Crushing; 3.
2 Living; 4. Plastic Sorting; 5. Office; 6. Active roof; 7. Storage; 8. Living; 9. Active roof;
3 10. Office; 11. Living; 12. Live/work; 13. Hair salon; 14. Narrow Street (3 metres)



5 Source: Author, 2023

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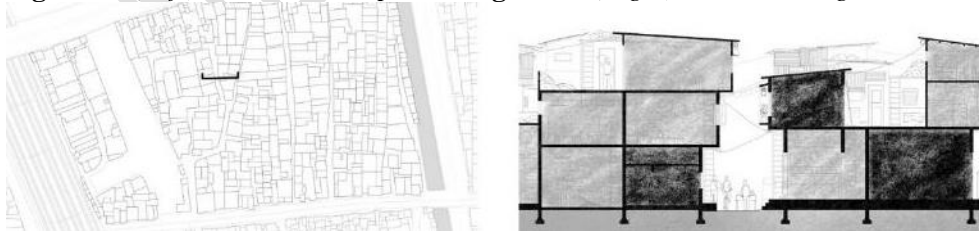
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Narrow Streets

The narrow streets in the 13th Compound range from two metres to five metres and are lined up with building entrances on both sides. These entries are usually set behind the large plinths which act as flood barriers and interaction spaces.⁴¹ The plinths also act as storage space in front and a base for the steep staircases to the floors above (Figure 78). The narrow streets allow minimum to no vehicular transportation and are generally limited to two wheelers and bicycles. The waste and recycled materials are exchanged and transported further using hand cart and barrows. These streets host more personal shops on the ground floor like grocery stores, hair salon and offices which are related to the community in the 13th compound. A series of electrical wiring can be seen hung around buildings, and over streets, showing illegal usage of electricity. Colourful Clothes are dried over the street and a very vibrant looking elevation of shanties are seen.⁴² Waste and recycled material storage are seen everywhere on the roads.

22 **Figure 76.** (Left) Location in compound; **Figure 77.** (Right) Live work diagram



24 Source: Author, 2023

⁴¹Dovey and Tomlinson.

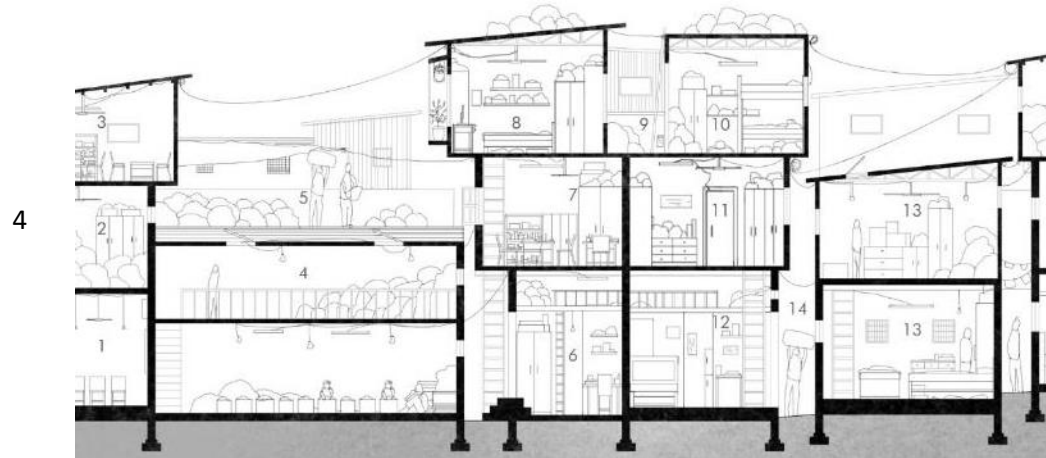
⁴²Dovey and Tomlinson.

1 **Figure 78.** *Narrow Streets*



2
3 *Source: Urbz, 2007*

Figure 79. *Narrowest Lanes Inhabitation* 1. Church; 2. Storage; 3. Office; 4. Plastic Sorting; 5. Active roof; 6. Living; 7. Office; 8. Living; 9. Active roof; 10. Live / work; 11. Living; 12. Living; 13. Living; 14. Narrowest Lane (1 metre)

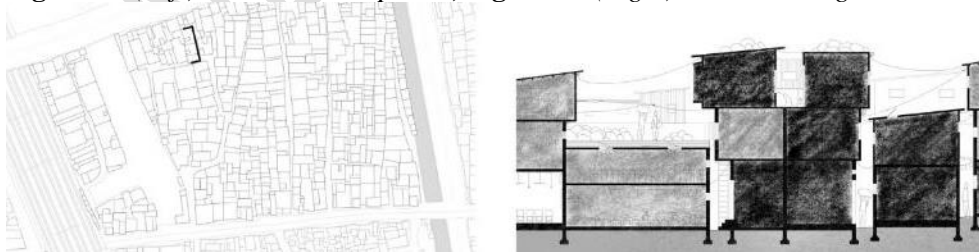


Source: Author, 2023

Narrowest Lanes

The smallest lanes of the 13th Compound range from 0.7 metres to 2 metres wide.⁴³ The main aim of these lanes is to provide easy passageways through the dense urban morphology of a slum. They are there to separate the shanties so that each house can at least have two open lanes and create some breathing space (Figure 8 2). However due to overhangs some of the buildings join.⁴⁴ Sometimes narrow routes are created through buildings on the ground floor to facilitate this strategy. The covered tops means that they do not allow any light to pass through, and ventilation is at its minimum. No vehicular movement takes place, and materials are delivered through them by people themselves. These lanes can only host informal storage at junctions when the road widens. Very steep steel ladders are on the roads itself and small yet raised plinths are seen all around to act as flood barriers. In some scenarios the house starts from the first floor and people have to commute down through the interiors.

Figure 80. (Left) Location in compound; **Figure 81.** (Right) Live work diagram



Source: Author, 2023

⁴³Dovey and Tomlinson.

⁴⁴Dovey and Tomlinson.

1 **Figure 82.** *Narrowest Lanes*



2
3 *Source: Urbz, 2007*

Construction

Incremental Building Process

Most dwellings in Dharavi are two to three storeys (Figure 83) with highest being four storeys. Overhangs extend to about 500 - 800 mm using I Beams (Figure 84) and are a key feature to enable external staircase access. All construction is done at a micro level of one room at a time. Ground floor constructions are generally finished with concrete and decorated with tiles and stone finishes.⁴⁵ Upper floors are supported with I Beams, and a lightweight construction method is applied on the floors above.

Figure 82. (Left) Typical constructed house; **Figure 83.** (Right) I Section Beams



Source: Dovey and Tomlison, 2012

Figure 84. (Left) A Shack at the start of construction; **Figure 85.** (Right) Fully completed shanty



Source: Flickr, 2009

⁴⁵Dovey and Tomlinson.

Progressive Construction

The houses in Dharavi are constructed progressively. Alterations and additions to the structure, materiality and interior are done incrementally as time goes by. As the dwellers gain economic stability and improvement; the house structures develop proportionally. Therefore, Dharavi houses range in quality - from a temporary shanty made up of bamboo sticks, wood beams and corrugated metal/asbestos sheet, to structure made of more permanent building materials such as bricks, concrete, I-Section Steel Beams, mortar, and plain cement.

Initially, a Dharavi House starts on the ground with the wooden/bamboo structure embedded into the soil. The wooden structure is the wall and roof skeleton which is covered by tin/asbestos corrugated sheets both on walls and roofs (Step 1; Figure 86). Tin sheets are generally used even after being high conductor of heat, which makes the indoor environment extremely hot and Improper overlapping and rust issues of tin are key problems leading to leakage and rainwater entering the house, this is tackled by using the blue tarpaulin sheets/similar plastic materials. Asbestos Sheets are used less frequently even after providing resistance from thermal heat as they are “known to be carcinogenic material”.⁴⁶

Once the family can support the upgradation financially, the wooden structure tends to remain as a skeleton, but the tin sheets are replaced with brick-and-mortar walls and concrete foundations are laid to build over. This transformation of the walls is gradual depending on the resources and materials available to hand. It could take up to a year for a family to get one wall replaced,⁴⁷ hence a few years to complete the ground floor. (Step 2 - 4; Figure 86)

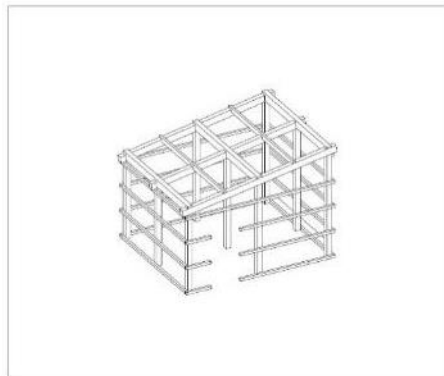
Families keep growing and migrating in, therefore demand of space increases, which requires the dwellers to build upwards. The floors above can support people from the same family and be used as a rent source from other families and recycling industries. At first, wooden frames are reused on the above floors to create instant space but later a similar procedure of a more permanent construction is executed by contractors. The upper floors are accessed using metal / wooden stairs to utilise maximum space inside. (Step 5; Figure 86)

This procedure is repeated till the third storey, but it reaches its peak then as access and construction above that becomes very difficult. The cantilevered floors and outside staircase strategies can be followed just up to three storeys. As strong foundations are not laid out adding more weight and overhangs would make the shanty structure fragile. (Step 6; Figure 86)

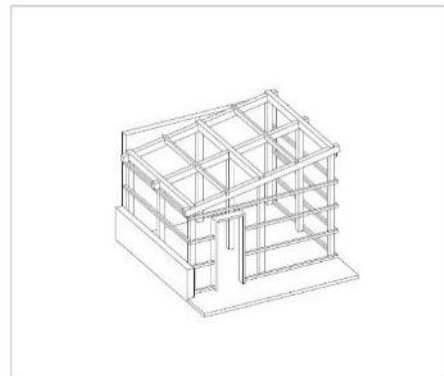
⁴⁶Sourav Dey, ‘The Circular Economy of Dharavi: Making Building Materials From Waste’, *PennState University Libraries*, 2018 <<https://etda.libraries.psu.edu/catalog/15724szd62>> [accessed 12 January 2023].

⁴⁷Dey.

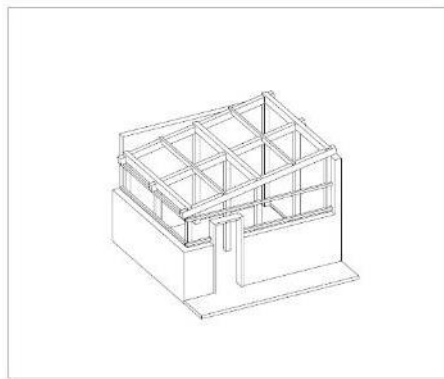
1 **Figure 86. Progressive Construction Drawing**



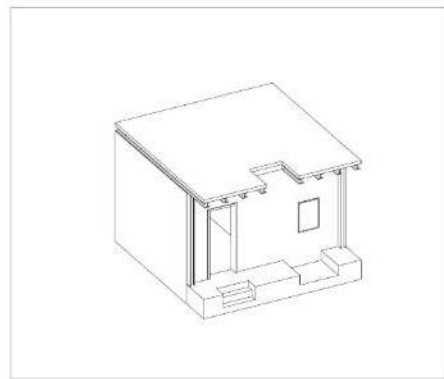
Step 1. Wooden Frame Structure with corrugated sheet



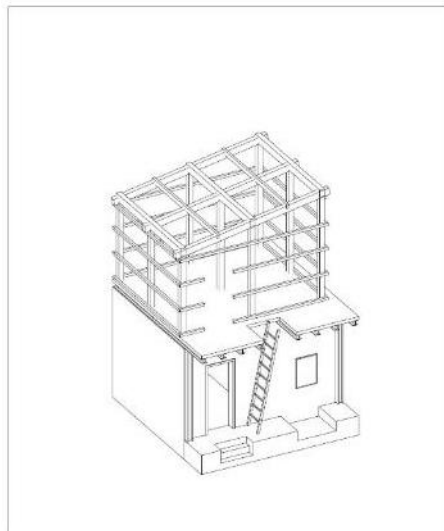
Step 2. Brick Wall starts to wrap the wooden structure



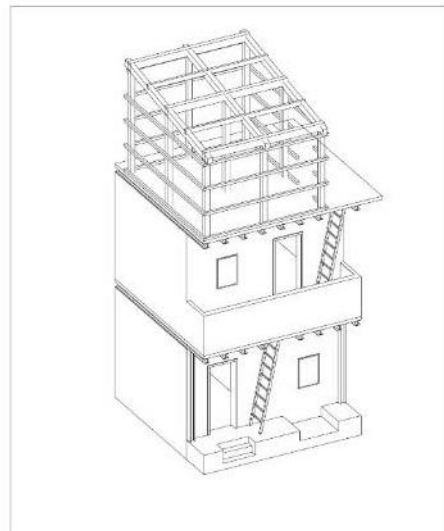
Step 3. Brick Wall wraps the whole structure



Step 4. Fully finished ground floor is ready



Step 5. Reuse wooden frame to build second floor



Step 6. Step 2 - 5 is repeated again to reach third floor

Source: Author, 2023

1 **Figure 87.** *Fully Constructed Shanty*



2
3 *Source: Urbz, 2007*

Materiality

Reuse, Recycle

The range of materials used for construction and housing are clay bricks, wood beams and studs, bamboo sticks, reinforced concrete, rusted iron sheets, I - Section Beams, corrugated asbestos, and tin sheets. Slate, ceramic, and clay tiles are used for the interiors. The iconic Blue Tarpaulin Sheets (Figure 88 and 89) are used to cover the roofs and as window during rainy seasons to stop rainwater from entering the houses. The tarpaulin sheets are also used as shading device during the summer season.

Figure 88. (Left) Roofs covered with tarpaulin sheets; **Figure 89.** (Right) Use of tarpaulin sheets on elevation



Source: (Left) Urbz, 2010; (Right) Urbz, 2007

Houses in the slums are made of mostly recycled materials with low embodied energy and follows pattern of incremental upgradation depending upon the monetary resources acquired overtime and the availability from waste materials that can be utilized for improving their homes.⁴⁸ But how does Dharavi receive waste material, Dharavi has connections and relationships with most operations and restaurants (Figure 90) around the city to send them their waste to be dealt with. It is a little like a recycling mafia chain.⁴⁹ This allows the informal recycling industry to thrive and create resources for construction and shanties.

Figure 91 shows a general concept of recycling and reuse in the construction of a house. I - Section Beams are sourced and used on the structures to create ceiling and support structure. Old wooden doors, window frames, grilles are salvaged and used on the house entrances. Tin and asbestos corrugated sheets are used for patchworks on the formal structures, and as main structures of the roof and top floor facade. Clay bricks are seen in general in the interior and outside plinths which stack up from waste materials. Plastic water drums are an important household product and come from the recycling industry if they are not good enough for the manufacturers.

⁴⁸Dey.

⁴⁹NUS and others.

1 **Figure 90.** *Waste Source Urban Map*



2 Source: Author, 2023
3
4 *13th Compound* *Waste Source*
5

1 **Figure 91. Material Taxonomy**



Source: Author, 2023

A Shanty

1:20 Model of a typical recycling, live/workhouse

The physical model brings in all the concepts of the research into a single piece of work. The model explains the themes of inhabitation inside the cramped living and

working spaces. It shows the ideas of a recycled and reused facade and exhibits the materiality of the building through scrap. Vibrant colour scheme, generated because of availability is also very clear from the elevations and interiors.

Focus on details, such as big blue water drums outside the house, electrical wiring running around the exterior and interior of the building, overhangs, plinths, external ladders, informal storage spaces, raised platforms interaction spaces, solid and lightweight construction all have been brought together in the model.

Diverse community, with the idea of owner and tenants have also been explored in the model, which is a key aspect of the live work environment in the 13th Compound.

Figure 92. *Construction Detail of the model*



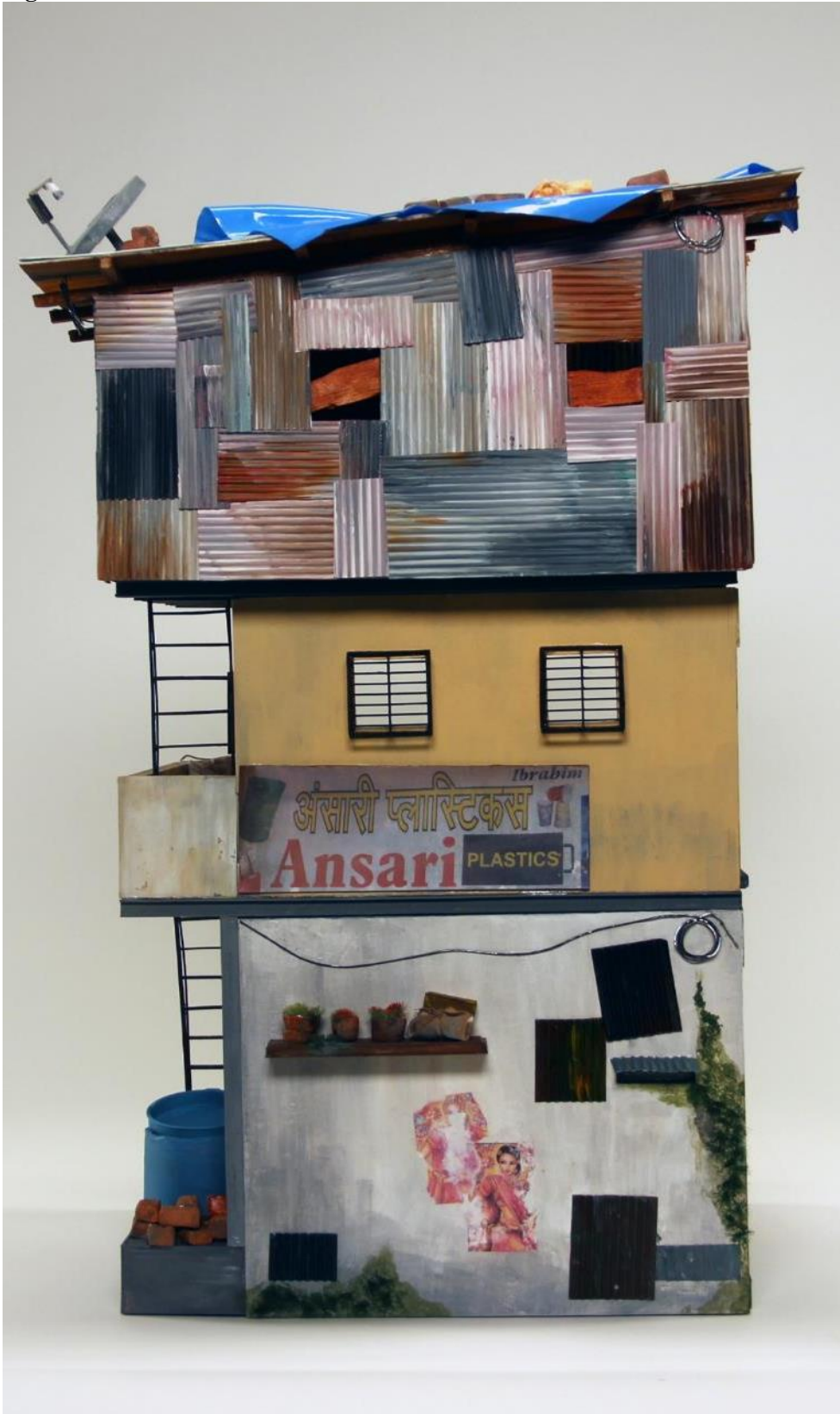
Source: Author, 2023

1 **Figure 93.** *Front Elevation*



Source: Author, 2023

1 **Figure 94.** *Side Elevation*



2
3 *Source:* Author, 2023

1 **Figure 95.** *Back Inhabited Section*



2
3 *Source:* Author, 2023
4

1 **Figure 96.** *Side Inhabited Section*



2
3 *Source:* Author, 2023

Conclusion

The recycling, live/work industry

Dharavi attracts people for the poor, unhygienic, unsanitary, and inhumane conditions which lack any type of infrastructure. However, what Dharavi has created is an industry which creates, manufactures, and develops everything to prove to the world that if the poor work in unity they can thrive and survive and create something extraordinary.

The 13th Compound is an example of this theory; an informal model of a circular economy and sustainability with its key point being recycling and live work. It manages to recycle 80% of Mumbai's solid waste and keep it free from landfills and garbage. It has created an industry hosting 1200 micro units, which has informally created jobs for approximately 300,000 people. The 13th Compound is an urban creative cluster as they do the best of what they do even in inhumane conditions, with a bit of innovation and improvisation. The western industry has much to learn; it can benefit from adapting to the observations made in the research and apply them by adding a set of building and living regulations to the existing case study of the recycling industry.

Key Observations

What makes 13th Compound easily accessible is the central location in the city and connection from main roads and railway networks (Figure 97) allowing the easy exchange and interaction in the industry. Inside the industry the horizontal nature (Figure 98) of the cluster makes it easy for the workers to send and bring in materials quicker. This makes the recycling process much efficient and faster and creates a continuity in the interaction of different processes. Mixed Used buildings (Figure 99) have created an active interaction in the residents and workers, and the workers save crucial time and money which would have been lost in commuting.

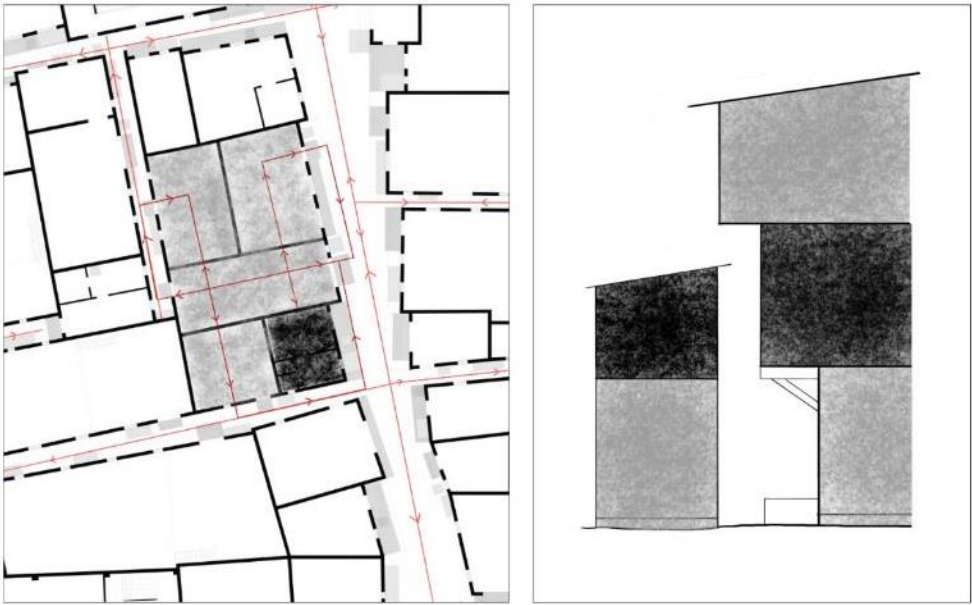
Figure 97. (Top) Centrally Located Industry

Figure 98. (Bottom Left) Horizontal Urban Growth

Figure 99. (Bottom Right) Centrally Located Industry



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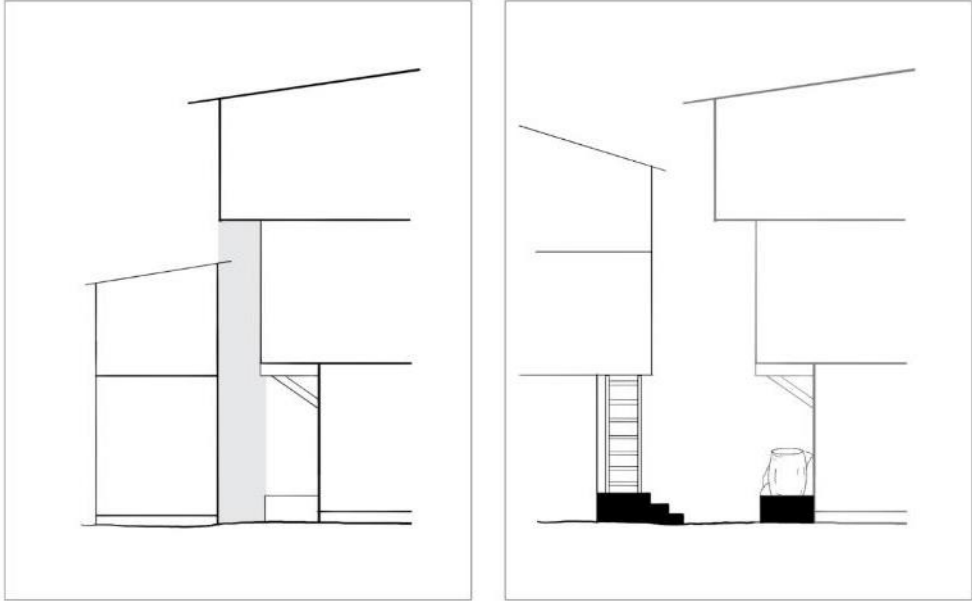
Source: (All) Author, 2023

Figure 100. (Top Left) Narrower Lanes

Figure 101 (Top Right) Plinth and Overhang

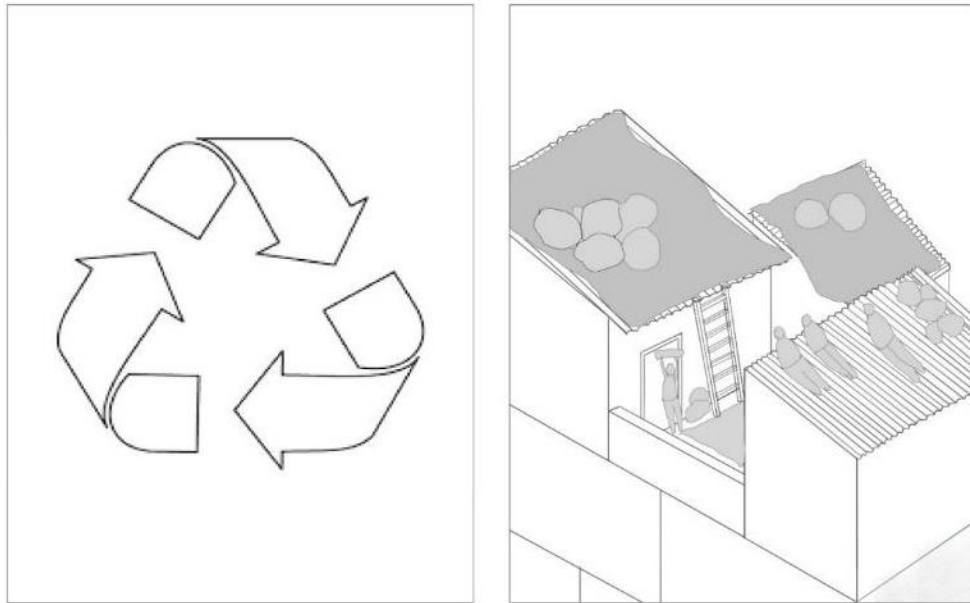
Figure 102. (Bottom Left) Re use, Recycle, upcycle.

Figure 103. (Bottom Right) Active Roofs



9

10



Source: (All) Author, 2023

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