

Semi-Nonstandard Construction and Its Application in Post-Squatter Istanbul

Stephen Form
Bachelor of Science, Art and Design
Massachusetts Institute of Technology, 2005

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Signature of Author: _____

Stephen Form
Department of Architecture
January 14, 2011

Certified by: _____

Nader Tehrani
Professor of Architecture
Thesis Supervisor

Accepted by: _____

Takehiko Nagakura
Associate Professor of Design and Computation
Chair, Department Committee on Graduate Students

Committee

Nader Tehrani
Professor of Architecture
Massachusetts Institute of Technology

Mark Goulthorpe
Associate Professor of Architecture
Massachusetts Institute of Technology

İpek Türeli
Postdoctoral Fellow in the History of Art & Architecture
Brown University

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Prefabricated buildings have long played a role in providing inexpensive, yet high quality dwellings for the multitude. However, such structures are typically standardized in nature and poorly suited for deployment within a crowded urban fabric. In İstanbul, where redevelopment projects have displaced many residents to standardized mass housing units built on the periphery of the city, another possibility for prefabricated housing may be possible.

In an age when CNC fabrication is becoming commonplace, the solution may appear to be nonstandard construction, whose potential in architectural discourse is frequently seen as an enabler of novel form making. Yet by strategically utilizing nonstandard tools in an otherwise mass-produced housing system, these techniques can provide variation within an industrial process while still taking advantage of the efficiencies of standardization.

This project proposes a method of construction that is based on a lightweight composite panel, into which have been collapsed the building's functional requirements (structure, insulation, weatherproofing). As part of their manufacture, the panels are modified utilizing this "semi-nonstandard" fabrication method. This process, which enables a far greater range of geometries and configurations than standardized construction, allows the construction of safe and efficient housing within the city center. This project proposes this system as a topic of architectural research and also as a social project, enabling İstanbulites whose homes are currently under the threat of expropriation to remain in their communities.

Thesis supervisor: Nader Tehrani
Title: Professor of Architecture

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Introduction

This thesis explores a model of prefabricating housing in İstanbul. Prefabrication has been a strategy of architectural production for millennia. Today, as lighter materials enter the building industry, there are potentials for new modes of fabrication that not only take advantage of the efficiencies of the factory, but take advantage of the power of distributed networks of production.

This thesis explores these matters in the setting of İstanbul. To a certain extent, this choice is arbitrary, but the city's sociological and historical circumstances make it an ideal testing ground for this project: the need for housing solutions within an existing urban fabric, the capacity for strong government aid to such work, and the tactical nature of the growth of the city.



Prefabricated Components and Assemblies

Prefabrication and its implications for the discipline of building have been a part of architectural discourse since around the time Le Corbusier published *L'Esprit Nouveau* in the 1920s, yet its earliest use in architecture predates the Modern Movement by nearly two millennia. And while today one thinks of prefabrication in terms of its relation to industrial production and standardization, the concept of off-site production is still most often used in the simple sense of displacing work to a more comfortable setting than the job site.

This distinction is between two primary modes of production: the off-site manufacturing of building components and the off-site construction of building assemblies. The former includes all the industrially fabricated elements of construction from fasteners such as nails and screws to building materials such as plywood sheets, dimensional lumber, drywall and brick. The latter includes the intelligent pre-planned configuration of these elements into larger elements of construction such as wall segments, programmatic modules, and structural bays. The implications for the introduction of industrially produced products has been theorized since the turn of the 20th century. As new techniques for fabrication are innovated, these theories need updating.

Preindustrial Prefabrication

Although it would be hard to come up with a date for the advent of prefabrication, the initial impetus for using this technique was, simply enough, the undesirability of building a given project in situ. Many builders of today decide to prefabricate parts of buildings as a matter of economics. However, the earliest examples of prefabrication — those from the Roman Empire — had much more to do with survival.

Certainly, the Romans advanced new building technologies for heavy structures throughout their centuries in power. And although impressive examples of their innovations such as the arch and dome survive to this very day, the Romans also left evidence, in the more humble settings of the Empire's outposts, of their contributions to the long history of prefabrication.

The Roman legions dispatched to the frontiers of the Empire made use of manufactured building materials such as nails and glass in many of their forts as such components could not be produced quickly on site. However, legions also carried with them larger assemblies that aided in the quick erection of defenses. The fortress at Inchtuthil in Scotland (Figure 1) shows evidence of being built from sophisticated prefabricated elements (Gibb 10). The even spacing of timber pilings to fit such assemblies was manifest in the stunning regularity of the overall plan of the garrison. Prefabri-

cated structures were not confined to military installations either. Archaeological findings show that Romans carried the building components for classical temples aboard ships travelling to the Empire's colonies as well (Bergdoll, Christensen and Broadhurst 12). In locations such as these, being able to quickly erect a structure was important for protective purposes, but it also made construction possible in unfamiliar territory with unknown resources available, and perhaps even served as a means of quickly asserting a position of power in a foreign land.

It is no surprise that centuries after the fall of Rome, Britain, with its vast empire, (and later, as a center of the Industrial Revolution) became a leading producer of prefabricated buildings. British explorers traveling to new colonies with harsh climates and unknown resources were motivated to build and disassemble their homes in preparation for their travels rather than build them on site at great pains. By the 18th and 19th centuries, settlers traveling to Australia were encouraged to bring fully prefabricated houses with them. Freetown, Sierra Leone saw settlers bring not only their houses with them, but also hospitals, churches, warehouses, and shops. Like the Romans before them, relying on local resources for shelter

¹ For a history of British innovations in prefabricated structures, see Herbert, Gilbert. Pioneers of Prefabrication: The British Contribution in the Nineteenth Century. Baltimore: Johns Hopkins University Press, 1978.

meant taking one's chances with unforgiving weather and potentially hostile local populations.

It could be said, then, that there were at least two major justifications for early prefabricated building systems. Firstly, off-site fabrication solved the problem of lack of resources on site, or, more precisely, the lack of familiarity with such resources. Secondly, it offered a way quickly meet the protective needs of this transient constituency. In the outposts of the Roman and British Empires, prefabrication was a matter of survival. It enabled alien populations to establish itself within foreign settings. Yet in the coming Industrial Revolution, the rise of iron construction and increasing mechanization of material production introduced new factors into the calculus of prefabrication.

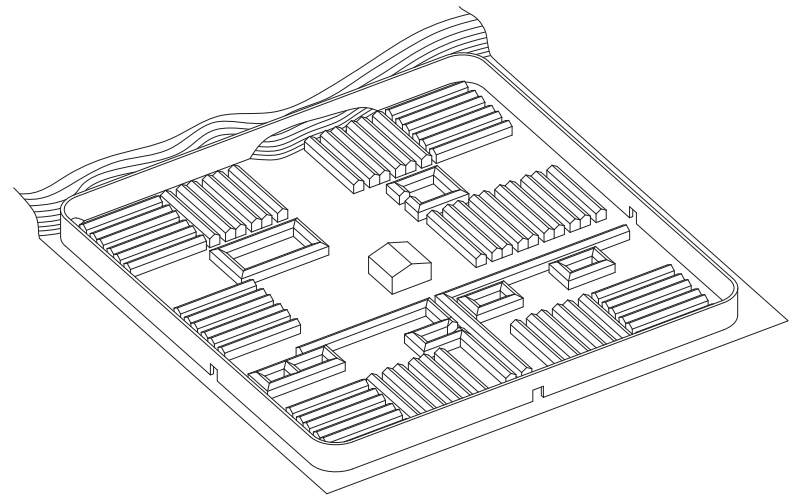


Figure 1: Layout of the fortress at Inchtuthil showing regularly spaced and dimensioned prefabricated barracks.

Industrial Standardization

At the end of the 19th century, innovations in the production of iron and steel had made these metals practical for use in construction and on a massive scale. Yet iron and the components made thereof, required heavy machinery and furnaces, devices not suitable for transportation. The use of iron, therefore, necessitated a shift in labor from the job site to the factory. Iron, in corrugated and cast forms, is a necessarily standardized building material as its components were made in factories that housed the furnaces and rolling machines that produced them. The advance of iron construction was but one example of the changing landscape of building materials brought about by the innovations of the Industrial Revolution.

Technological advances, like the improvements made to the blast-furnace in the 15th and 16th centuries, were the prelude for the increase in availability of iron that formed the basis for the Industrial Revolution. By the 19th century, iron production was becoming much more efficient. These developments brought greater focus on the fabrication tools required to shape and cut such materials. Concurrently, the increased power of steam hammers, and, later, hydraulic hammers, enabled more complex shapes to be produced from newer, more ductile versions of this metal.

Yet the spirit of innovation was not confined to iron. Concurrently, other materials, like plywood, were developed with the new tools of the time. Plywood, patented in 1865, relied on the efficient cutting of veneers from lumber, previously achieved only by hand planers. The 1890 invention of the rotary cutter, which could produce continuous veneer sheets from a log, combined with advances in resin and press technology, made plywood a commercially viable building material by the early 20th century (Ngo and Pfeiffer 18-20).

With these repetitive processes in industry, all elements produced therefrom were necessarily standardized in some way. Iron, for example, formed using castings or stampings, were churned out in high volumes in like forms. Plywood sheets were trimmed to sizes determined by the length of the rotary cutter and the depth of the press bed. Dimensional lumber, already in production, had been refined using more powerful and precise saws.

Industrialization, therefore, not only led to advances in traditional building materials such as lumber, but brought new ones to market like corrugated iron and engineered wood.

Until this point, mechanical production and building prefabrication were processes used in series. Despite the advances in each, the ability to truly mechanize building production remained elu-

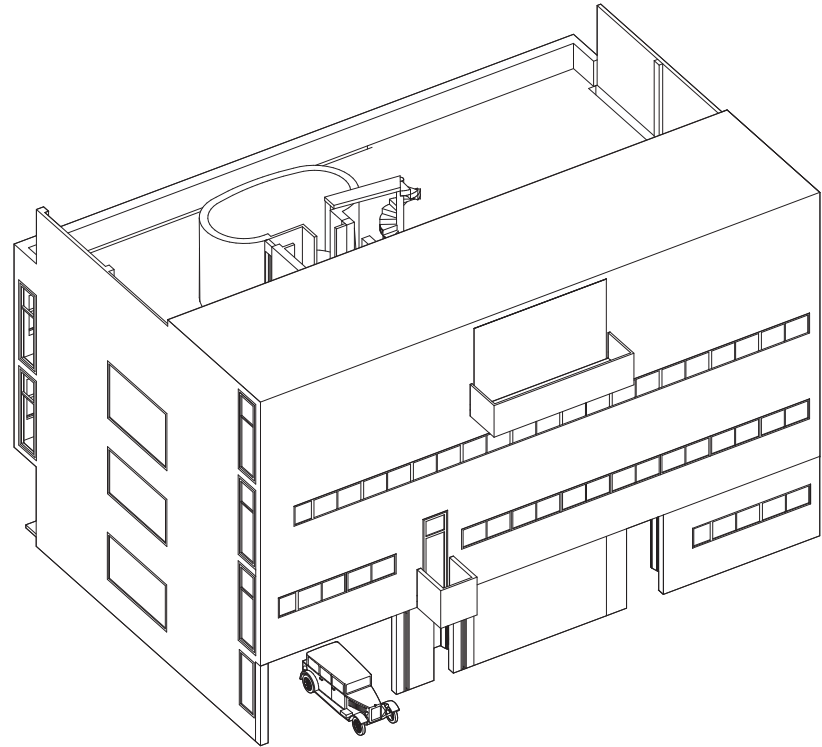


Figure 2: Villa Stein by Le Corbusier and Pierre Jeanneret with Voisin car in garage.

sive. As in the examples of the Romans and British, prefabrication in architecture simply involved traditional means of construction that were simply displaced to a factory floor. In the 20th century, architects and designers struggled not only to merge mechanical and architectural production, but to theorize what this transition would mean to architecture as well.

At this transitional moment, a debate arose on the influence of mechanization on architecture. Across Europe, adherents to older traditions formed ideological groups like the Arts and Crafts movement which rose up in opposition to the effects of industrialization on the decorative arts. Other design schools, like Art Nouveau and Jugendstil, were producing forms whose very uniqueness seemed to be an rebuke of standardization and industrialization.

Yet at this time there was also the ascendancy of a group of architects who sought to incorporate the new aesthetics of industrialization in their work. Le Corbusier, in his *Vers une Architecture*, lays out a case for a machine inspired architecture, comparing images of mass-produced automobiles like the Model T with classical and contemporary architectural paragons (Figure 2).

Even before Le Corbusier's manifesto, architects struggled with the rise of industrial production in architecture and design. The

Deutscher Werkbund, a cooperative effort between designers and manufacturers, was founded by the German government to improve the country's industrial products. Influenced by the Werkbund, Walter Gropius's early pedagogy at the Bauhaus preached a unity of craft and building not for the purpose of creating fine craftsmen, but to eventually train students to improve the quality of mass produced goods. Later, Gropius began to further embrace standardized production of architecture as a matter of economy. This interest stayed with him after his move to the United States, where he developed, with Konrad Wachsmann, "The Packaged House" which utilizing a patented joint system.

Industrial fabrication built up a catalog of materials from which nearly every building today is constructed and therefore, one may, with some justification, call most constructions prefabricated. The early 20th century featured a great deal of thinking about how this change would affect architecture.

Contemporary Customization

Prefabrication has become important in the past century as the economics of construction have changed. The rise in the cost of labor and increasing demands from clients have made efficiency — in terms of material, time, and cost — a paramount concern in most major building projects.

In a typical construction project involving no preassembly, components — dimensional lumber, insulation panels, bricks, weather-proofing, to name a few — are first produced in a factory and then brought to a site and assembled by skilled workers. A prefabricated construction project adds a third step in between the factory and the site by configuring groups of these components into larger assemblies. This process displaces the effort of skilled labor to another facility chiefly to achieve some new efficiency. Modern-day prefabrication could be viewed as an effort to introduce some of the same efficiencies to the building assembly process that industrialization did to the material creation process. Typically, this involves the displacement of work.

There are numerous advantages to moving this process off-site and, as is almost always the case, indoors. In addition to the comfort of workers, temperature and humidity control means components may be brought together and fastened without continual expansion and contraction that may harm glues and paints as they cure

and dry. Indoor assembly allows trimming of components using more sophisticated tools and smaller tolerances. Finally, work can be conducted more efficiently because surfaces may be positioned at comfortable heights for laborers. All these benefits confer improvements in the three parameters that define the so-called project triangle.

The project triangle (Figure 3) defines the relationship between three criteria of a given task: quality, affordability (also called “cheapness”), and speed. Oftentimes, it is said, there is only the capacity to achieve two of those three goals, but it may also be useful to view any given project as a point resting closer or farther from any of those poles, or, in three dimensions, as a pyramid resting between points on three axes representing the three criteria.

While value engineering determines the position of the “point” representing the project’s priorities, new technologies may change the range of values of the parameters in the triangle. The standardization of components pushed the limits of the project triangle beyond where they stood in the preindustrial era, allowing for a higher degree of precision at a lower cost and a faster speed, than could be previously achieved. Similarly, the efficiencies of prefabrication may allow work to produce a better quality product faster and cheaper than on-site operations may (Figure 4).

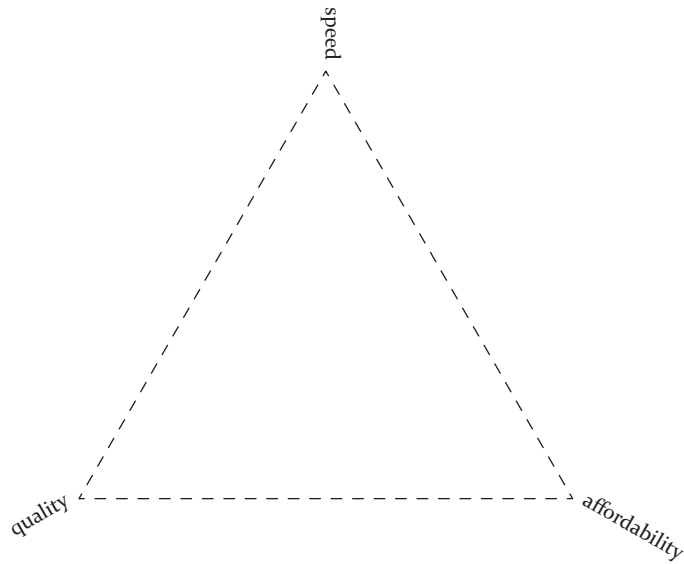


Figure 3: Work triangle as planar triangle.

In this mode of thinking, as much of the building should be built off-site as transportation and handling capacity will allow. This has created a trend towards larger and larger prefabricated assemblies. The single wall panels from the Roman and British barracks have been enlarged to room-size modules and even entire structural bays.

Another key process in the development of prefabrication has been the rise of computer aided manufacturing. The invention of computer numerically controlled (CNC) machining created the possibility of rapid production of differentiated parts. The result of this

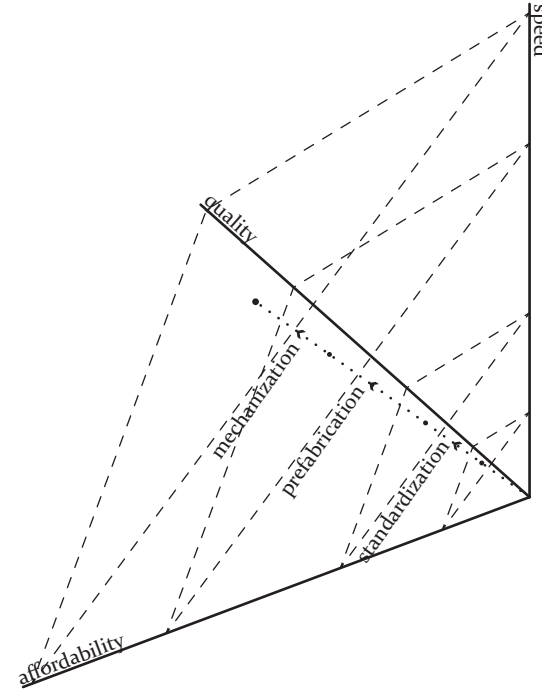
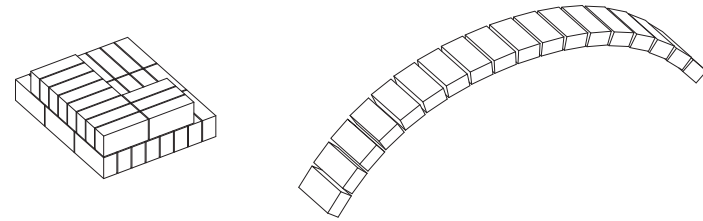


Figure 4: Work pyramid with shifting boundaries.

new fabrication process was seized upon by architects who used it to actualize forms previously too unrealistic to build. The 1990s witnessed a wealth of projects that featured novel formal expressions. The work of Frank Gehry, Zaha Hadid, Greg Lynn, and NOX all pioneered, in design and, gradually, in built work, new nonstandard potentials in architecture.

The relationships between prefabrication, manufacturing, and efficiency can be seen through a simple comparison of two methods of constructing the same form (in this case, an arch): one through brickwork and the other through stonework.



**Brick Arch Model:
Low Skill Prefab, High Skill Assembly**

A brick arch (Figure 5) is constructed utilizing several standardized elements. However, at the job site, these elements must not only be properly positioned on the scaffolding, but joined to one another. When such bricks take the form of an arch, the mason must account for the angle changes by varying the thickness of mortar between adjacent bricks. Here, efficiencies over a poured-in-place concrete arch are achieved by use of industrial elements, yet manual effort is still required to finish the assembly.

This model comes close to approximating the way in which material like dimensional lumber and plywood are formed into a single-family house. All the pieces may be standardized, but require special consideration when joining them. With certain floor-to-ceiling heights, one may even be able to use materials like plywood and gypsum board without trimming them.

Hector Guimard's Paris Métro entrances are another example of the brick arch model, albeit on an individual component and for aesthetic ends. Despite the emphasis of Art Nouveau on organic forms, like those of bones, insects, tree branches and flowing hair, the necessity to work in iron made it important to use repeating elements wisely. While the most prominent elements of the station entrances are the cast iron columns and railing shield orna-

Figure 5: Brick arch made from varying joint thicknesses.

ments, the balusters show an intelligent modification of standard elements like I-beams (Figure 6). Here, a targeted operation allows enough variation in the designs possible so as to achieve Guimard's aesthetic goals while taking advantage of the efficiencies of industrial products. Here, the prefabrication step is the standardized material itself.

This process of construction may go incredibly fast, as the steps to create joints may be simple for a trained individual (like a mason, carpenter, or ironworker). However, as the process begins with standardized materials of smaller size, the number of joints/connections/cuts may be very large. As this number of discontinuities in material increase, so, too, does the possibility for errors in construction. Therefore, as a general rule, it is better to limit the amount of work done on a prefabricated element after the prefabrication step.

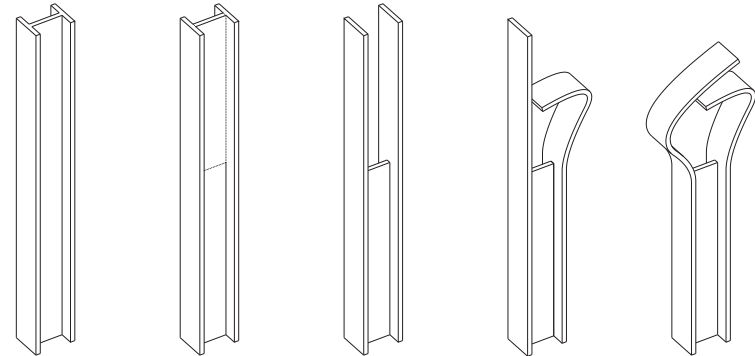
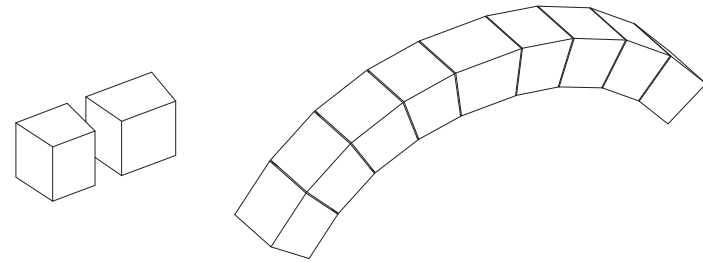


Figure 6: Modification of an I-beam in Paris Métro balusters.



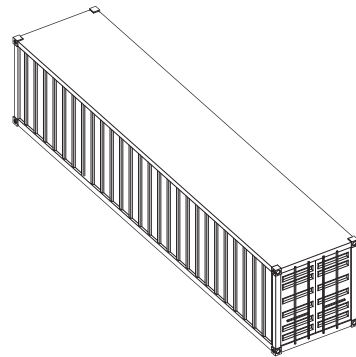
**Stone Arch Model:
High Skill Prefab, Low Skill Assembly**

The stone arch (Figure 7), unlike the brick one, uses a non-standard, albeit prefabricated element. While a mason must carve the stone to the shape necessary, the assembly itself requires little skill. When placed, the stones ideally align automatically face to face. In the case of many stone arches, little to no mortar is necessary, and ideally, no variations are made in the assembly step. Of course, the stone arch as built in the past was carved more or less on site so as to check and recheck its fit with neighboring stones. However, the process of stone carving and stone setting could theoretically be segregated.

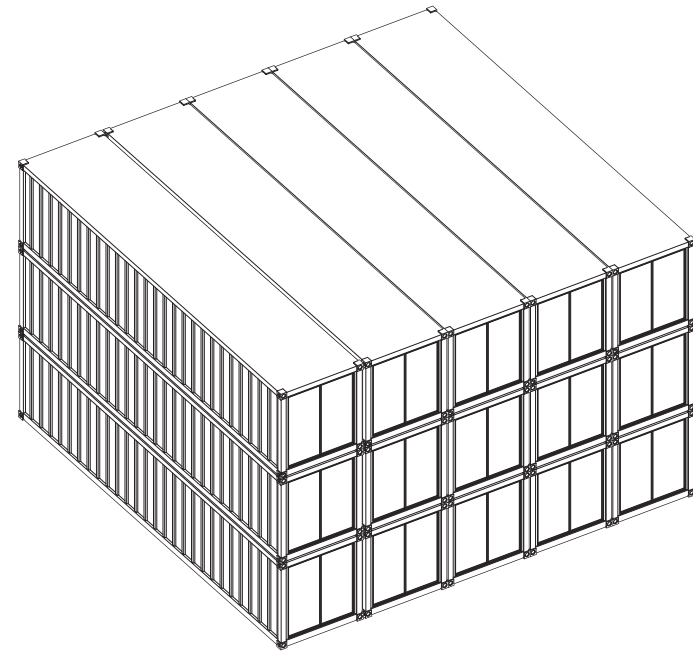
Because of the inherent ease of joining units and despite its outward formal qualities, shipping container architecture represents an apex of this mode of prefabrication (Figure 8). The shipping container has attracted the attention of architects and few offices have as much at stake in the implementation of shipping container architecture as the New York office of LOT-EK. The justification for this focus is the ubiquity of the container. LOT-EK exploits the container in the same manner as one might use other materials at hand like timber, stone, or brick (Scoates 67).

The allure of the container as architecture is evident upon seeing the vernacular use of these volumes. The Yuen Long district near the port of Hong Kong utilizes the castoff steel boxes as buildings

Figure 7: Stone arch made from varying stone geometries.



intermodal shipping container



Keetwonen Student Housing
Amsterdam, NL

Figure 8: Shipping container architecture typically involves efficient packing of prefabricated units.

to support various activities related to the port: offices, workshops, storage (Bertin, Daqing and Pui Leng 12-13). The Dordoi Market near Bishkek, Kyrgyzstan uses shipping containers not only to store the goods that arrive there, but act as the stalls and structure of the market as well (Rothschild 20).

Each LOT-EK project involves an additional step before the placement of the volume. While for the stone, it is the geometrical shaping of the element itself, here it is the careful dissection of a factory-produced component — shipping container, airplane fuselage, concrete mixing drum — and the outfitting of these volumes

for inhabitation through shop processes. In order to produce the custom interiors of these spaces, one use to craft-based techniques.

As mentioned in the discussion of the brick arch, it is best to limit the number of operations done on site. This makes the shipping container project appealing because it is one of the largest volumes that can be conveniently shipped in a single piece.

In order to vary the geometry of a prefabricated structure, it is necessary to use nonstandard elements. Today, the creation of such components is far easier largely due to new technologies in milling and machining.

The challenge is to create a housing prototype that can be produced almost as rapidly and cheaply as standardized components, but to vary the geometry of the final form so as to fit in sites of nonstandard geometry. Can a mechanized process of fabrication offer a way to accomplish this goal?

Rarely does an architectural design need to account for the mechanization of its production. It is atypical that an given project will require a component produced as many times as, say, the hood for a specific car model (of which millions will be produced) and therefore, it is uncommon that a project is granted the investment of time and money necessary to create the fabrication tools to shape such parts.

The invention of computer numerically controlled machining created the possibility of rapid production of unique parts. As mentioned earlier, the result of this new fabrication process was seized upon by architects who used it to actualize new forms.

Yet many of these firms could spot other potentials. Projects like NOX's myHouse and Greg Lynn's Embryological House foresaw the possibility of using CNC machines to produce endless variations of single family homes to fit the needs of their users.

Yet these projects remained provocations for one primary reason. While these new technologies could produce precise 2d cuts to create structural skeletons, and precise 3d molds for skin elements, the creation of buildings involves the confluence of not only these two systems, but layers of insulation, wiring, plumbing, waterproofing, etc. These various components are typically installed by various groups on a job site at separate times. Only through a fusion of these systems could such visions be realized.

Furthermore, the time it takes to cut entire components from blanks, to say nothing of the wasted material left over from such operations, is significantly greater in nonstandard fabrication than the analogous industrial processes of punching and molding. The creation of a nonstandard lightweight composite component requires time spent curing in an autoclave and additional time cooling (Figure 9). These steps severely limit the scalability of nonstandard fabrication processes.

What lies unexploited is a realm between a solely CNC-enabled nonstandard architecture and an efficiency-centric standard prefabrication. A project that incorporates these two processes might be called semi-nonstandard. It would enable mass-produced projects to escape the poverty of a standardized, uniform architecture. With the addition of a minimum number of custom steps

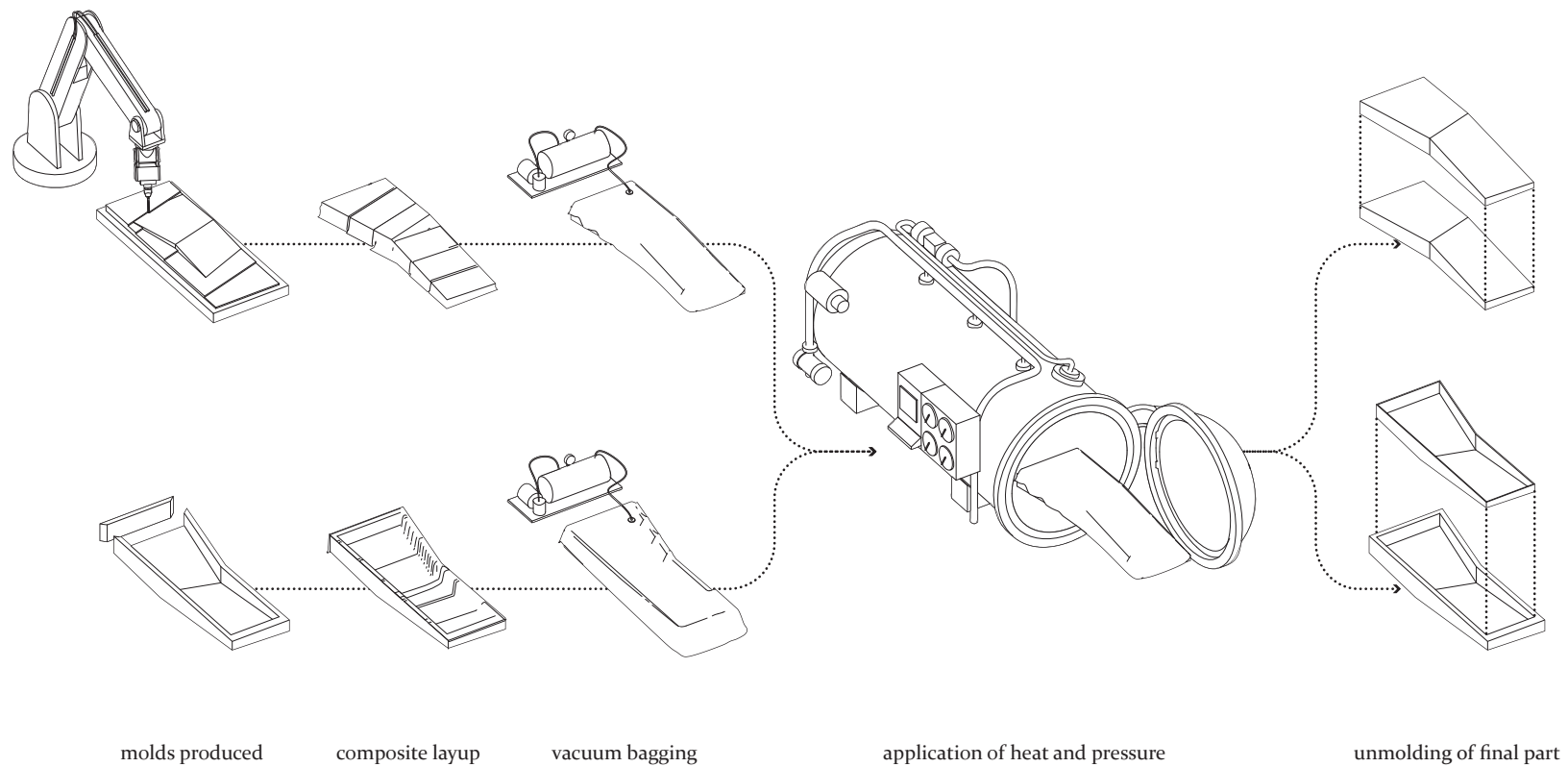


Figure 9: Fabrication of non-standard geometry from lightweight composites.

into an assembly line process, a good degree of freedom of form-making may be achieved (although it would not enable the frivolity of many entirely nonstandard architectures). It would also, through the mechanization of architectural production, advance the efficiencies of prefabrication beyond the mere displacement of manual labor.

The proposal made in the third chapter of this book discusses the specifics of such a semi-nonstandard model in İstanbul, how lightweight materials may be incorporated into this process to provide advantages in terms of material usage, quality, and speed, as well as how the fabrication process itself may become a useful social project in the city as a whole.



İstanbul's Three Modernizations

Turkey's emergence as a modern nation is commonly thought to begin with the declaration of the Republic of Turkey in 1923. However, this transition to modernity had been taking place since the Ottoman Empire. In the 18th century, the Empire, humiliated by losses of territory in Europe, began to adopt Western military organizational strategies to stanch this string of failures (Gül 7).

The modernization of the city of İstanbul has been a continuous struggle for its administrators. The government-directed planning proposals of the late Ottoman Empire made gradual changes to the city over the course of decades, albeit ones that fell far short of the visionary proposals made for it. After World War II, it was the industrialization of the nation, rather than planning, that remade the city. Immigrants from rural Turkey flooded into the city, expanding its boundaries and filling empty hilltops with new houses. The growth accelerated, sponsored by an administration with no resources to accommodate the influx of new İstanbulites.

At the turn of the 21st century, however, this self-service model of development was made illegal, and the city now faces a crisis as the government seeks to redevelop the city under formal rules. It faces opposition from landlords, squatters, and tenants whose homes are under threat of expropriation.

Top-Down Planning from the Late Ottoman Empire to the Early Republic

With the reforms during this period came new ideas about the organization of cities. İstanbul, the capital and most populous city in the Empire, had been the subject of serious introspection. Foreshadowing a trend that would emerge nearly two-hundred years later, Abdullah Efendi's Memorandum to the Ottoman Court in 1792 suggested that mature nations were those that would solve their problems according to "sedentary rules," meaning that they needed to provide the services of established cities such as garbage collection.

Major planning proposals for modern İstanbul started with the 1839 planning policy. Since then, new plans or commissions were set up in 1856, 1868, 1878, and 1910. The new Republic of Turkey established a planning office whose most celebrated boss, Henri Prost, submitted a master plan for the city that was adopted in 1939. Of his proposals, only a few projects for new roads and parks were implemented. Prost's successor, the Permanent Planning Commission of 1952, did not fare much better (Gül 139).

Large planning proposals had a poor record in İstanbul. The project of modernizing the city has only been realized in piecemeal fashion. Each plan for the city drawn up by the planning commissions resulted in the construction or widening of a few roads, the

laying of a few sewer lines, or the clearing of a small area of derelict housing. While these projects, taken as a whole, have all been important steps, none have had the transformative power that, say, Hausmann's Paris plans had. In fact, Hausmann was invited to İstanbul in 1873. The result of his work had no implications on the planning of the city; he proposed a new model for collecting taxes (Gül 52). Modern İstanbul, for some reason, has resisted visionary development.

While the latter half of the 20th century was a period of massive migration to İstanbul, the city's population had a long history of sudden growth spurts (and, of course, declines). The successive losses of territory by the Ottoman Empire in the Russo-Ottoman War in 1878 and in World War I led to an influx of refugees from these ceded lands. For instance, within a period of three years after the loss of Bosnia-Herzegovina and Bulgaria, İstanbul's population more than doubled to 87000 (Gül 55).

At the dawn of the 20th century, the city had just over a million residents. However, the decline of the Ottoman Empire brought with it a decline in the prestige and population of the old capital. By the time of the declaration of the Turkish Republic, the city's population had dropped by almost a third, to under 680000.

Mustafa Kemal Atatürk, the founder of the Republic, had located the headquarters of his military campaign during the Turkish War of Independence in Ankara. After the war, the formerly unimportant city was declared the capital of Turkey. Free from the historic and religious burdens carried by İstanbul, Ankara was to be a modern, secular city, emblematic of the new nation's Kemalist values.

With the movement of the capital, İstanbul's growth stalled. Although the city's population decline eventually halted as the nation began modernizing, planning efforts were still hampered by lack of investment. Henri Prost's notable work in the city led to some improvements, yet lack of money meant they could only be partially implemented (Gül 109). At the end of World War II, the city's population stood at around 860000, still below its peak. In the years to come, the city would see a greater population growth than ever, brought on not by careful planning, but by a deluge of urban pioneers from the countryside.

The Gecekondu and Unplanned Modernity

In World War II, Turkey was a neutral power. As the victory of the Allies became apparent, Turkey's politicians declared themselves on the side of the Western powers, making their nation eligible to funds made possible by the Truman Doctrine and Marshall Plan. Hundreds of millions of dollars in aid as well as technical experts in infrastructure flowed into the country. Roads and rail lines were laid throughout the country to make room for Turkey's anticipated rise as a major agricultural source for Europe. Soon, agricultural production was mechanized after the influx of fleets of American-made tractors. However, even as arable land increased area from 16 million to 25 million hectares from 1948 to 1960, jobs disappeared from the countryside (Gül 129). The jobless rural population moved to the cities in order to escape poverty and look for new jobs. From 1950 to 1970, İstanbul's population tripled due largely to immigration and the growth of immigrant families (Keyder 146).

While the population boom in İstanbul after World War II was brought on by national and international investments in the mechanization of agriculture and the expansion of industry, the newcomers were housed in structures built largely by individuals. Turkey's cities did not have the capacity to provide housing for the new İstanbulites, yet, as mentioned, it did have one thing in abundance: open land.

In the Ottoman Empire, land was not a commodity that could be bought or sold. All land across the Empire belonged to the Sultan, who granted portions of it to administrators who could then rent the land to citizens. The use of the land, however, was a legally protected commodity, meaning empty, unappropriated land had little value. In fact, a law in the Empire allowed an individual to take over an empty lot so long as he provided it with a use (Keyder 144). The land ownership structure was formalized gradually, but accelerated after the declaration of the Turkish Republic in 1923. However, the attitudes about the importance of tenancy survived. This legal perspective formed the basis for one of the main development tools of the urban newcomer: the gecekondu.

The gecekondu has been an important housing type in İstanbul since its first appearance in the years following World War II. The word "gecekondu" is a Turkish concatenation meaning "placed overnight." The building arose during this time according to a Turkish law that states that if someone erect a building at night and be moved into their house by sunrise without having been caught, the structure may stay until a court hearing has taken place (Neuwirth, *Shadow Cities* 147). The gecekondu was itself a solution to a housing shortage caused by an influx of immigrants, but its ascendancy was the result of various idiosyncrasies in the Turkish

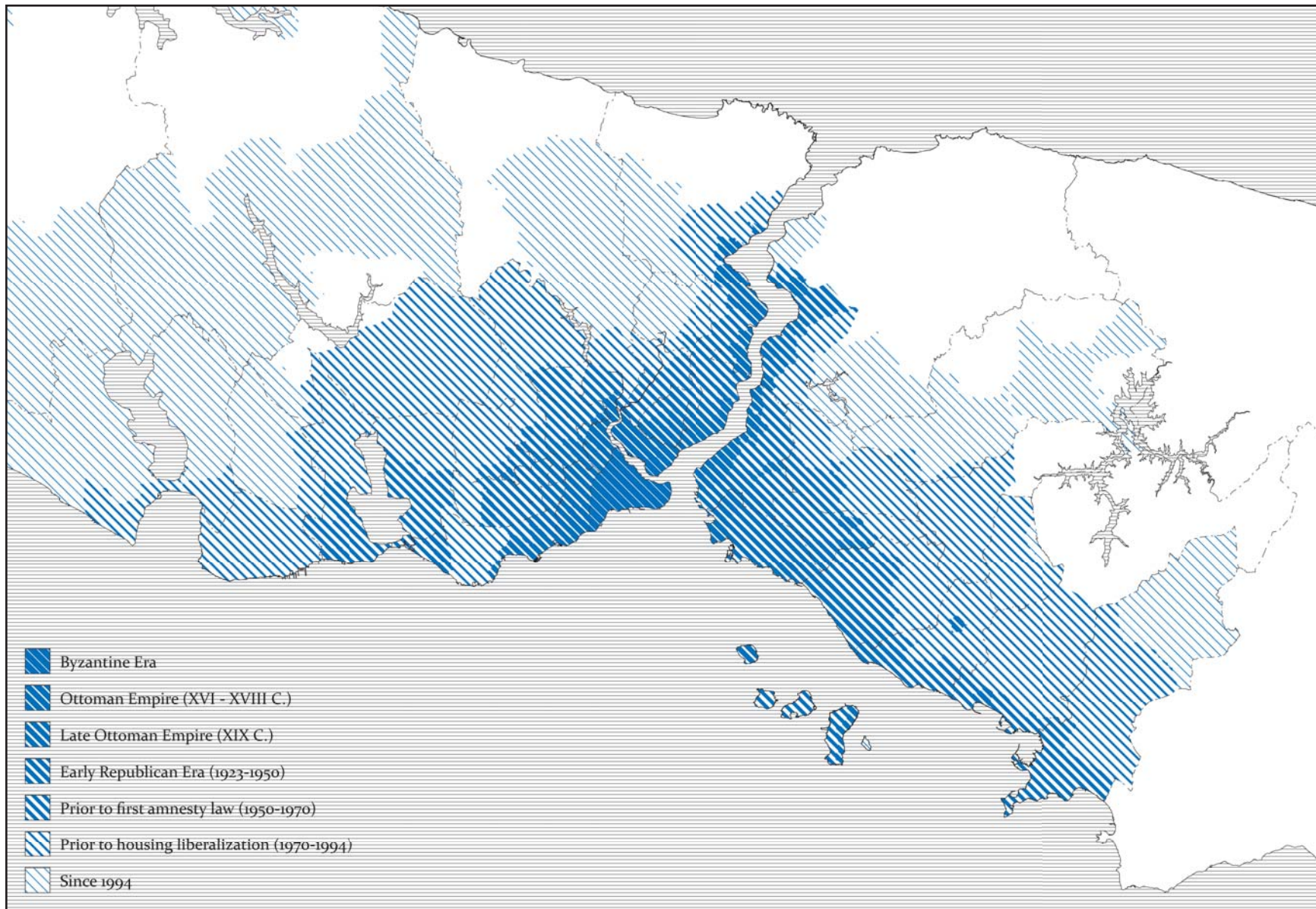


Figure 10: Dates of original settlement of neighborhoods in İstanbul.

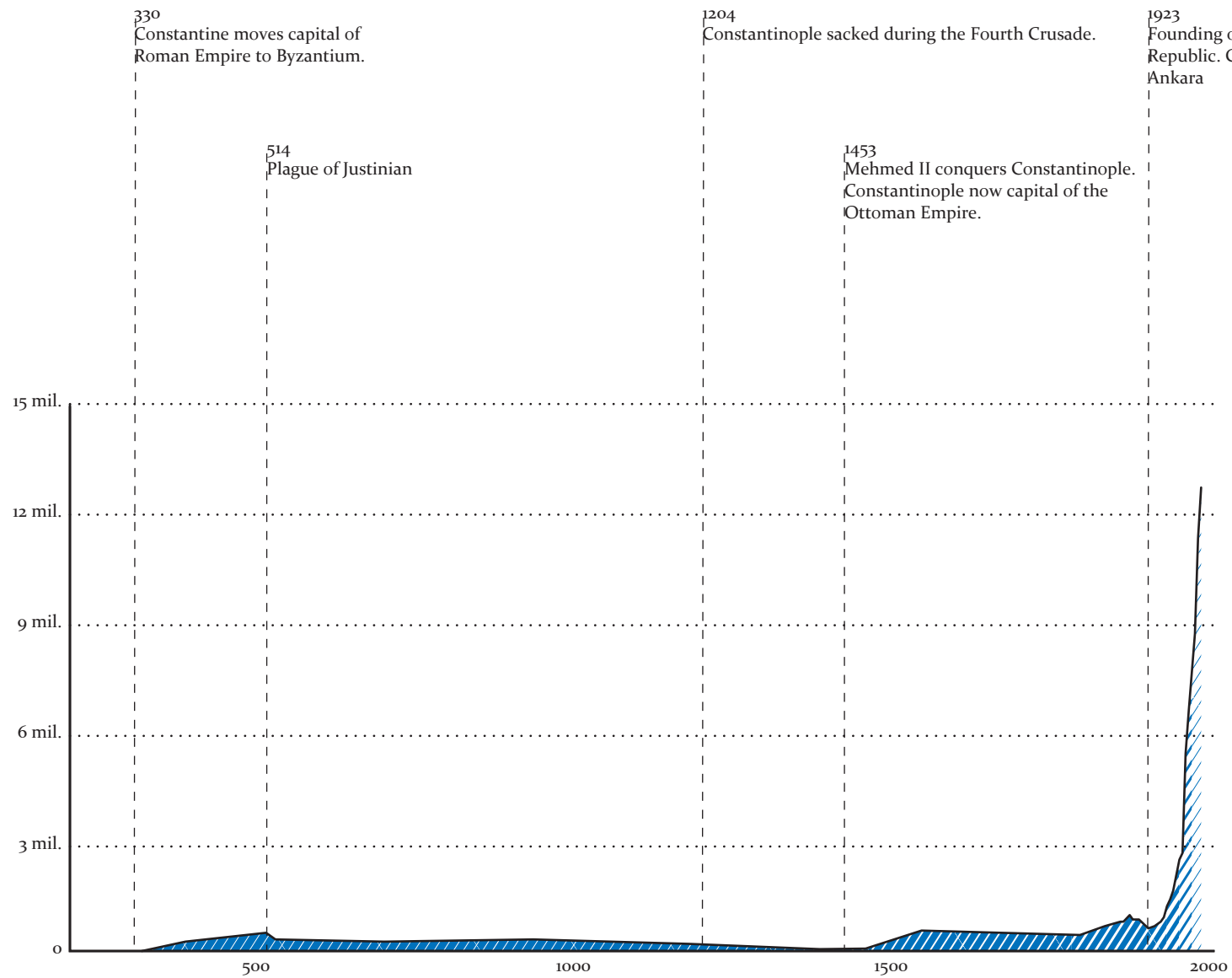


Figure 11: Timeline of population growth in İstanbul since year 1 CE.

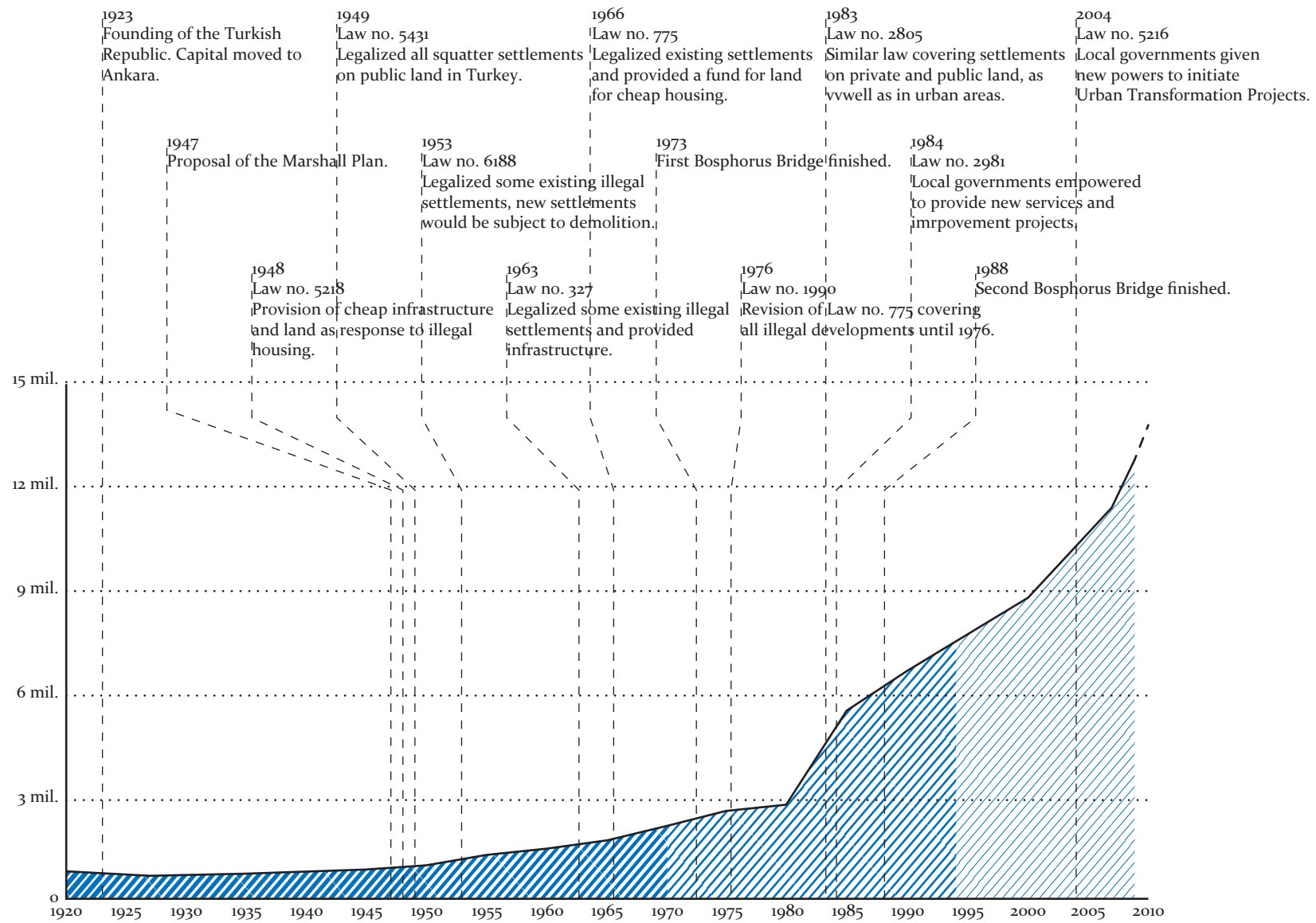


Figure 12: Timeline of population growth in İstanbul since year 1920.

policies on land ownership as well as a series of laws passed in the second half of the 20th century (Figure 12).

Immigrants to the city constructed *gecekondular* at a rapid pace. The first sites for such houses were the open areas in the central city; gardens and vacant lots became building sites. Unoccupied structures, left from the decline of the city after 1900 were again populated too. As the historic center was being filled in, immigrants found land on the periphery of the city. Such developments often grew on hilltops over valleys occupied by the factories at which squatters worked. These suburban *gecekondular* often allowed settlers to maintain some measure of their rural heritage such as gardening or raising chickens.

The government at first disapproved of such constructions, yet eventually, *gecekondular* became part of a *de facto* development process in the city. The legal basis of the *gecekondular*'s existence was a result of both bottom-up activism and top-down political maneuvering.

In Turkey, squatters are allowed to organize after their community reaches a certain size. Even in the 1950s, *gecekondu* residents had lobbied the city to be provided with infrastructure (Nalbantoğlu 206). Once a community grows to 2000 residents, it could ask

the city to form a municipality. The leaders of these communities are asked to supply them with infrastructural improvements. Although they are not often able to do so, they are instrumental in lobbying for utilities for their constituents (Baharoglu and Leitmann 124).

Meanwhile, the legitimization of *gecekondu* housing was a strategic decision by those in power. The squatter populations, who could vote not only for local officials, but higher offices as well, made them an important constituency. Populist politicians often made campaigns pledges to fight for title deeds of settlers. The cause became so strong, that within a few years, support for *gecekondu* rights almost ubiquitous.

A series of amnesty laws were passed, granting land ownership to many *gecekondu* dwellers. In 1966, the first of these (No. 775) went into effect. The law granted land ownership and provided infrastructure to many existing settlements, planned the demolition of *gecekondular* deemed unsafe, and opened up public land to development to increase the housing stock of the city (Baharoglu and Leitmann 119). These laws typically featured four components: legalization, servicing, demolition, and land liberalization, all with the intent of slowing the *gecekondu* growth rate. Subsequent amnesties in 1976 (Law No. 1990), 1983 (2805), and 1984 (2981) con-

tinued the trend of concessionary measures. However, little could be done to stem the tide of gecekondular construction. From 1965 to 1970, the number of gecekondular increased by a third, from about 430000 to 600000 (Aksoylu 7).

The amnesty laws had unintended and significant consequences. Not only did they fail to stop gecekondular construction, they led to the redevelopment of these squatted lands, as newly minted landowners and entrepreneurs built larger structures, apartmanlar, on the sites of older buildings they built or purchased. In successive waves of opportunism, Turkey's urban pioneers, both those seeking to secure a foothold in the city by building a gecekondular, as well as those hoping to profit from the shifting regulatory milieu, changed the face of the city. As İstanbul's population exploded, so, too, did its building stock: new apartmanlar sprouted on previously empty hills and from gecekondular neighborhoods.

These small-scale construction projects were made possible by the yapsatçı, a phrase roughly translated as "one who builds and sells." Under this system, a land or homeowner would contribute his property and the yapsatçı his building skills, and they would share ownership of the units the new apartman, sold to paying tenants who finance the construction materials (Esen and Lanz). The yap-

sat system formed new units within the city by building upwards, providing, in turn, cheap housing for many of the city's newcomers.

To produce as much profit for the investing parties as possible, the apartmanlar were constructed quickly and cheaply. Low-quality cement and inadequate rebar was used in reinforced concrete structures. Concrete was frequently unconsolidated and plastered over. Weather barriers and insulation were not added to buildings.

Both the capitalist yapsat and the individualist gecekondular systems came to transform the city of İstanbul by both densifying the city and spreading it outwards. These informal methods of construction not only housed, but also, through amnesty laws that legitimized such buildings, created wealth for entire new classes of İstanbulites. As the 20th century drew to a close, however, the forces of global capital and a shifting political climate put an end to the self-service city.

Formalization of the City

In 2009, Turkey's Public Works and Settlement Minister, Mustafa Demir, called for the demolition of all illegally constructed buildings in the country by 2015 (Yavuz). In İstanbul, where more than half of the existing housing can be classified as illegal (Keyder 143), this declaration would, if implemented have devastating effects on the social and formal makeup of the city.

By that time, a confluence of political and economic changes made the presence of informal housing in the city far less tolerable than it had been in the past. The lack of code compliance for such a large percentage of the city was viewed as an embarrassment to the country as they prepared their candidacy to join the European Union and sought foreign investment in their nation. In the two hundred years after Abdullah Efendi's Memorandum, the administrators of İstanbul failed to impose "sedentary rules."

Years earlier, in the 1980s, this process of formalization began under the center-right Motherland Party (ANAP). The ANAP passed a series of measures that deregulated financial markets and trade and privatized various public functions. In İstanbul, where the ANAP held the mayorship, policies favored the move to a service sector economy to attract global investment. It was in this era that the business district Levent was planned on the site of a major industrial area.

The shift from the populist policies of the amnesty laws to a liberal model of development can be traced to the rise of the Justice and Development Party (AKP) spurred by the economic crisis of 2001 (Kuyucu 122). As part of their recovery strategy, the AKP hoped to attract foreign investment to Turkey but felt that the *gecekondular* and other informal housing, especially in İstanbul, diminished the attractiveness of the city to these constituencies. It was this desire to provide an infusion of cash to the city that sparked the desire to "solve" the *gecekondular* problem.

New laws were passed that effectively gave the housing authority in the country, TOKİ, the power to redevelop large sectors of the city. These efforts, known as Urban Transformation Projects (UTPs), displace residents of areas dense with informal housing to mass housing projects elsewhere. The vacated land is then available for sale to private developers.

Subsequent laws expanded these powers. TOKİ was given the ability not only to administer almost all public urban land, it could also autonomously build and sell housing on that land or create private entities to be their partners in these development projects. From 2002 until 2010, TOKİ was responsible for the construction of nearly 100,000 housing units in the city with dozens more in planning stages (Figure 13).

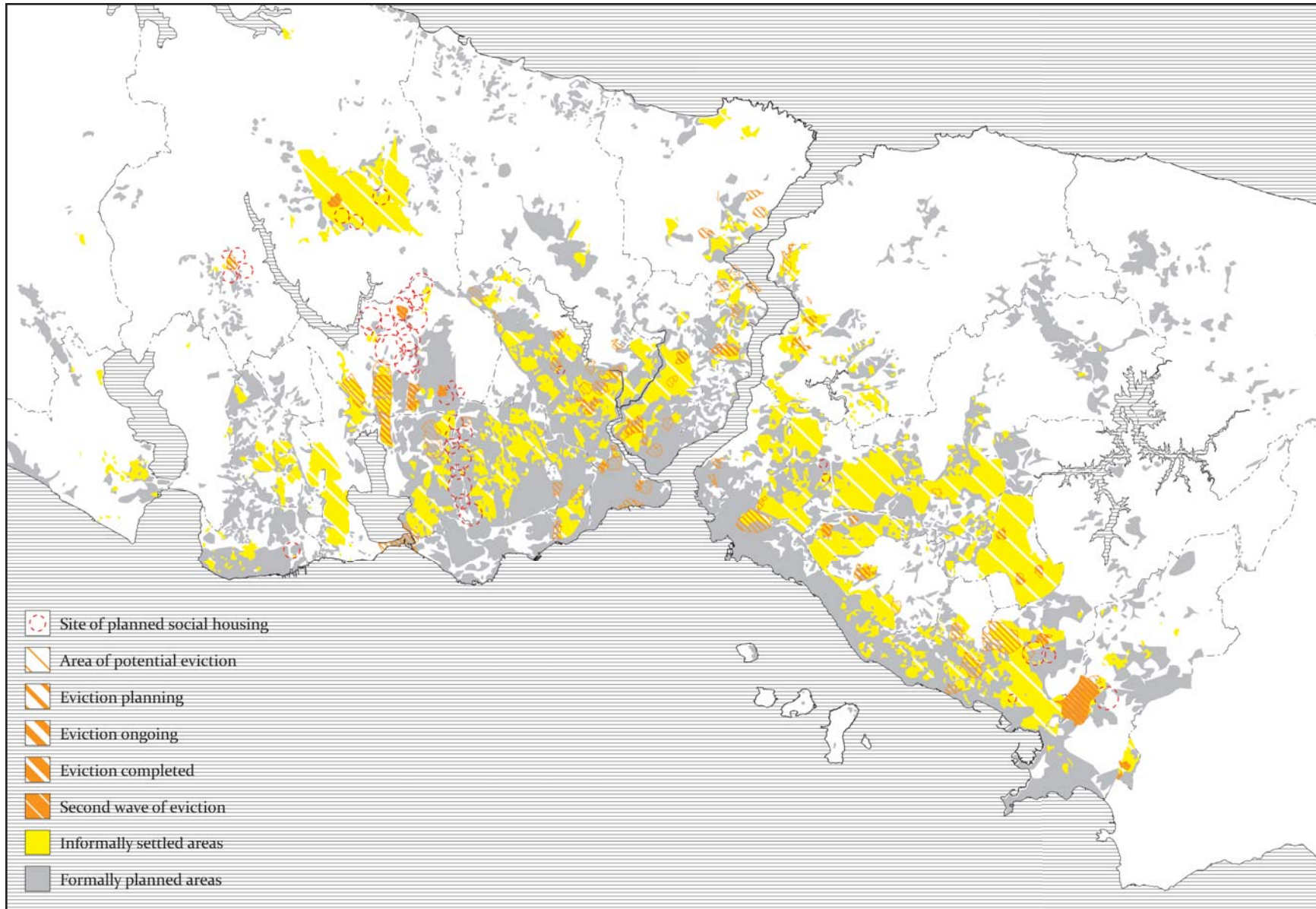


Figure 13: Informally settled areas and redevelopment proposals in İstanbul.

In making the case for such projects, the government has mentioned the urban renewal potential of these efforts: slum clearance, crime reduction, and the creation of safe, earthquake-resistant housing. Yet the evicted residents were either unable to unwilling to pay the rents in social housing projects built for them up to a three hour commute away from their old homes and communities. The individuals living in areas designated for redevelopment, many of whom have lived in the city for generations, are often thrust deeper into poverty with less opportunity for finding a job than they had in their previous home. All this is to say nothing of the siting of already marginalized areas for UTPs. For those within the redevelopment zone, the eviction process can be long and painful.

Yet as torturous as to social implications can be to neighborhoods, there is, indeed, the very real threat of a major earthquake. Seismologists predict İstanbul will suffer an earthquake with a magnitude greater than 7.0 in the next thirty years. The cheaply produced building fabric of the city makes it especially vulnerable to seismic events (Figure 14). For instance, during the 1999 İzmit Earthquake, whose epicenter was nearly 100 kilometers away from the city, almost 100 structures in İstanbul collapsed and more than 400 people were killed (Bohlen). One study estimates that as many as 60000 structures — as many as stand in the entire Fatih District

(the Old City) — may be heavily damaged if such a massive earthquake hit the city itself. This study places the death toll of this potential earthquake at 90000, which would make it the seventh deadliest seismic event in the past 400 years (Afet 37) (United States Geological Survey).

Surveys of the city found widespread noncompliance with building safety standards. The directive of Minister Demir targets not only informally produced housing, i.e. *gecekondular*, but also buildings constructed on privately-owned land that was not built to code.

Therefore, the residents of İstanbul live under the dual threat of expropriation of their homes by their government and the destruction of their homes by earthquake. While retrofitting or replacing the entire illegal building stock of the city in time for the next earthquake is likely impossible, any housing proposal put into the city should have three primary objectives. First, it should be safe on its own. Second, it should not cause additional harm to the buildings around it in the event of an earthquake. Finally, it should, if possible, serve to reinforce adjacent structures to help prevent their collapse.

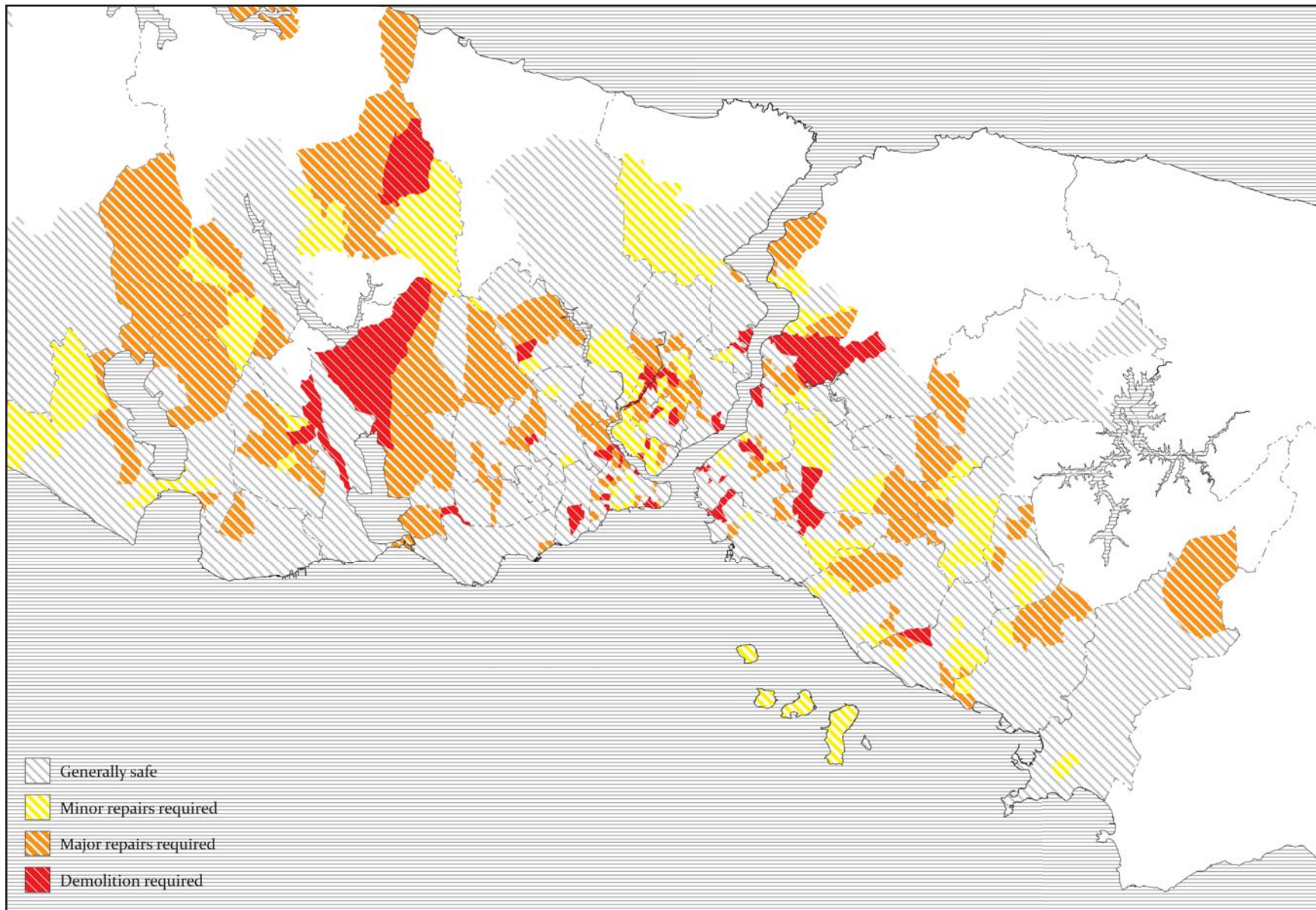


Figure 14: Average building earthquake retrofit needs by neighborhood.



Prefabrication and Manufacturing in İstanbul

İstanbul's unique growth pattern has created a city filled with a patchwork of different housing ownership structures. For example, a block may be home to an owner-occupied gecekondu, an apartman with three families renting from a landlord, an apartman with an absentee landlord, and a condemned structure occupied by squatters. Therefore, the process of redeveloping a given area of the city involves a long and complicated process of negotiation with these various constituencies. Although the government has exercised a great deal of leverage in such dealings and has become quite successful at this process, it has recently been seen more as an antagonist in communities near redeveloped areas.

These projects often displace large numbers of people to mass housing away from their existing communities. To create housing as cheap as possible for these individuals, the government uses standardized building construction methods. Here, the use of prefabrication can most efficiently be implemented on clear sites because these standard elements have no way to negotiate specific site conditions. However, this proposed system allows displaced residents to be rehoused in structures built within the fabric of the city while using local labor. The process relies on three interrelated innovations: a mobile or distributed fabrication facility, lightweight materials, and semi-standard production.

Fabrication Overview

The production of new housing in İstanbul has the potential to not only be safe and cheap, but also may be integrated into the history of housing construction of the city. As mentioned earlier, the construction of large swaths of the city were executed by individuals and other small groups looking to either carve out a home for themselves or to achieve some measure of social mobility. Today, that mobility is threatened by redevelopment projects which potentially displace residents to distant mass housing structures.

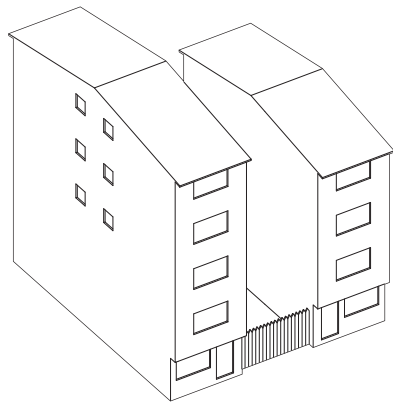
As the city seeks to attract foreign investment, it is crucial that land for redevelopment is opened up. Typically, landlords, in exchange for their cooperation are given units in the project being developed. This arrangement works out well for them but poorly for their tenants. This project proposes that all the residents of a given community agree to hand over properties to the government (or the cooperating development agency) in exchange for assistance in redeveloping the remaining area of the city in order to house the displaced residents.

The government would provide money for a fabrication facility which would aid in the construction of new units to be placed within the remainder of the neighborhood. The units may be placed on any number of vacant sites, including collapsed or condemned buildings (Figure 15). Additionally, small buildings may be

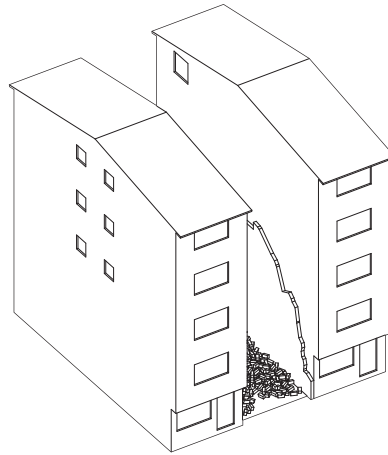
rebuilt taller so that families may achieve new sources of income. Other buildings may even cap existing structures with new ones to provide another rent-paying unit to the apartmentman.

The raw materials for these projects may be purchased from the cheapest sources possible, but by quickly moving these materials into the country, the government can provide another way to fuel Turkey's economic engine. Furthermore, by embedding the fabrication process within the community itself, the city's low-cost housing market can be reinvigorated.

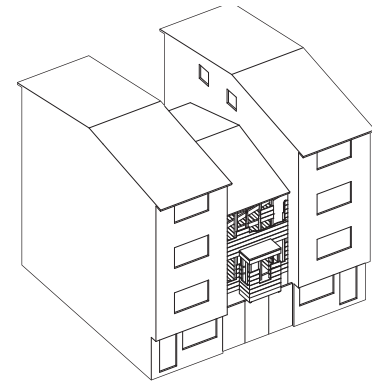
During the construction of units at these sites, local labor can be used in both assembly and, after a training period, in the prefabrication facility. These jobs would provide a useful, if temporary, stream of income for many residents of the community, but can also provide skills that can be used as more of these facilities are created. Essentially, the process itself uses money from the redevelopment of land to provide jobs, homes, and skills to individuals who would otherwise be dispossessed of their apartments and livelihoods (Figure 16).



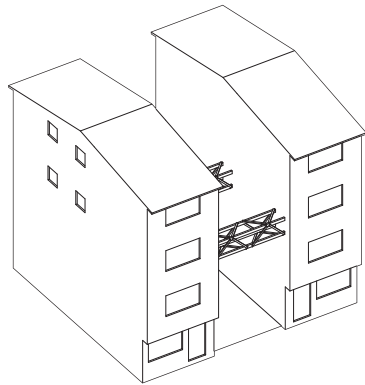
empty lot



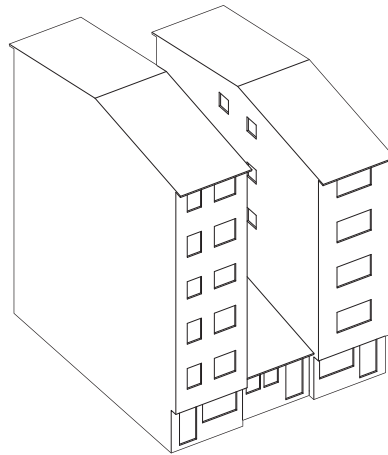
collapsed building



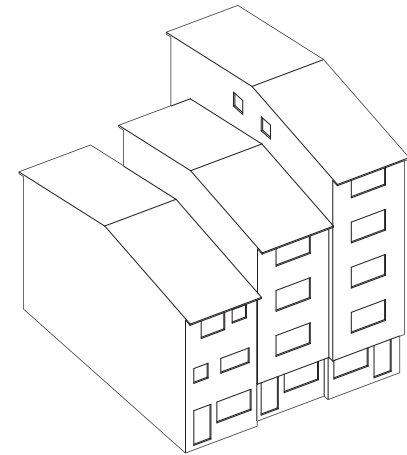
condemned structures



truss-supported buildings



sandwiched one-storey structure



low-rise buildings

Figure 15: Building site potentials within the urban fabric of İstanbul.

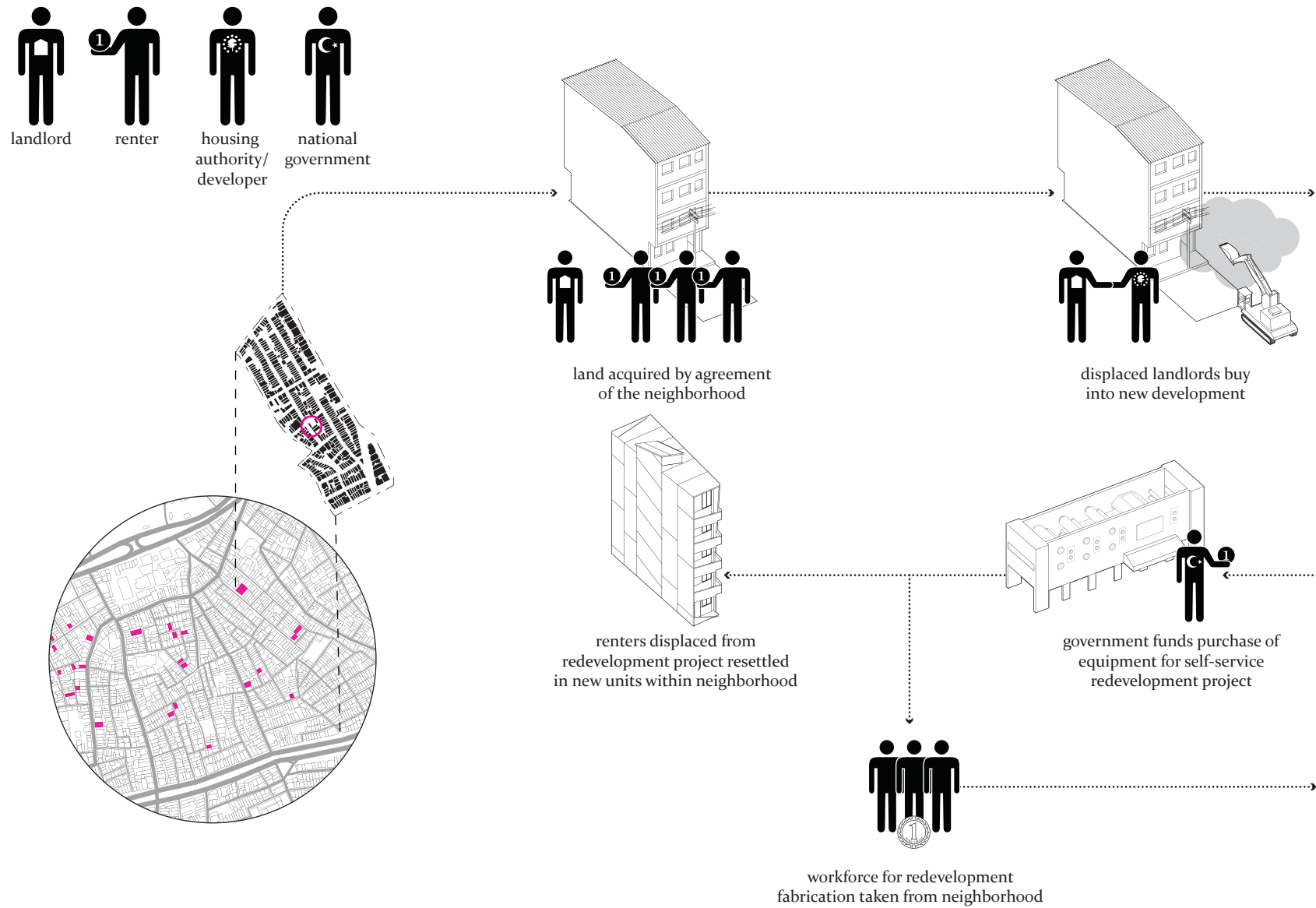
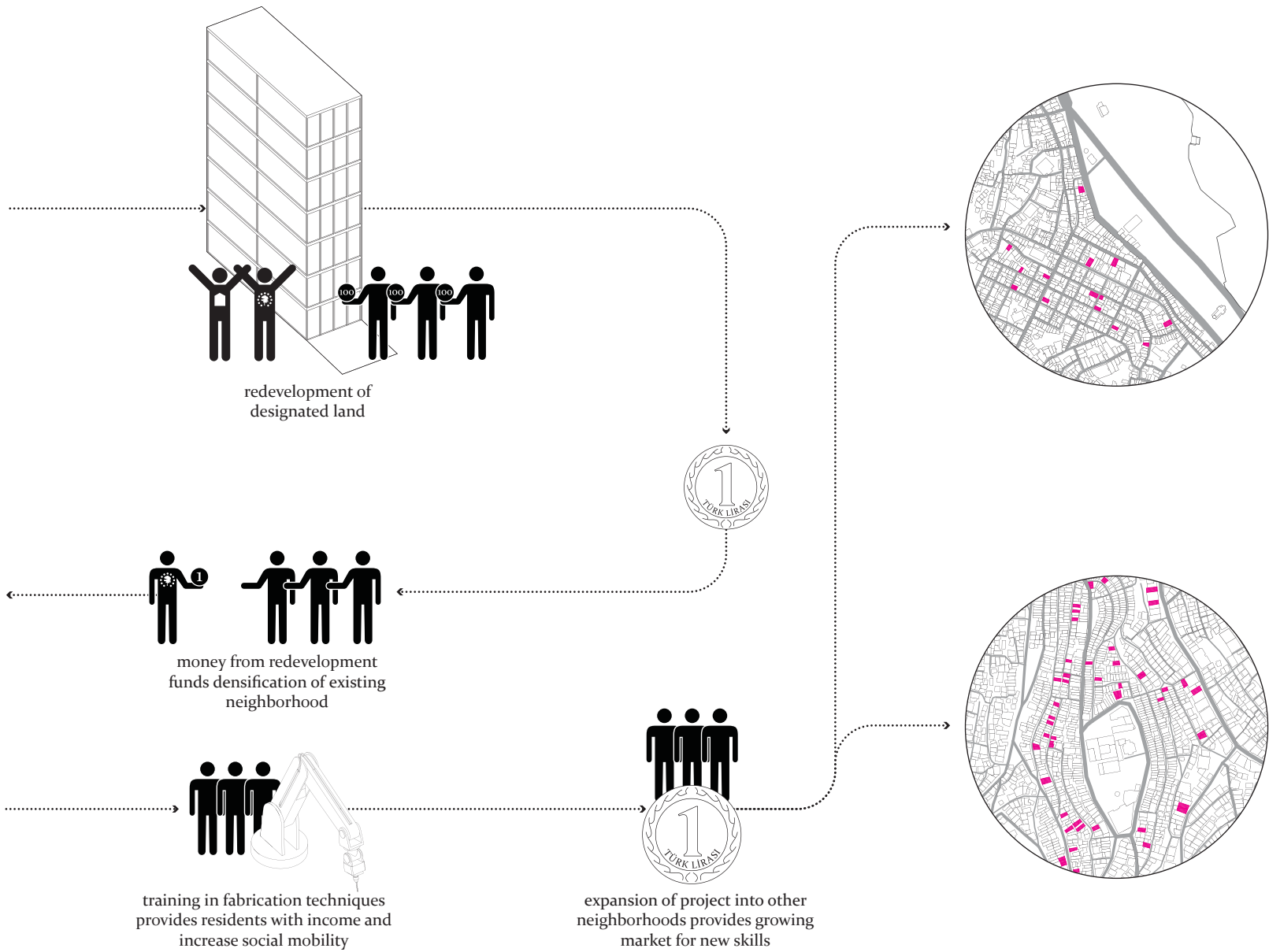
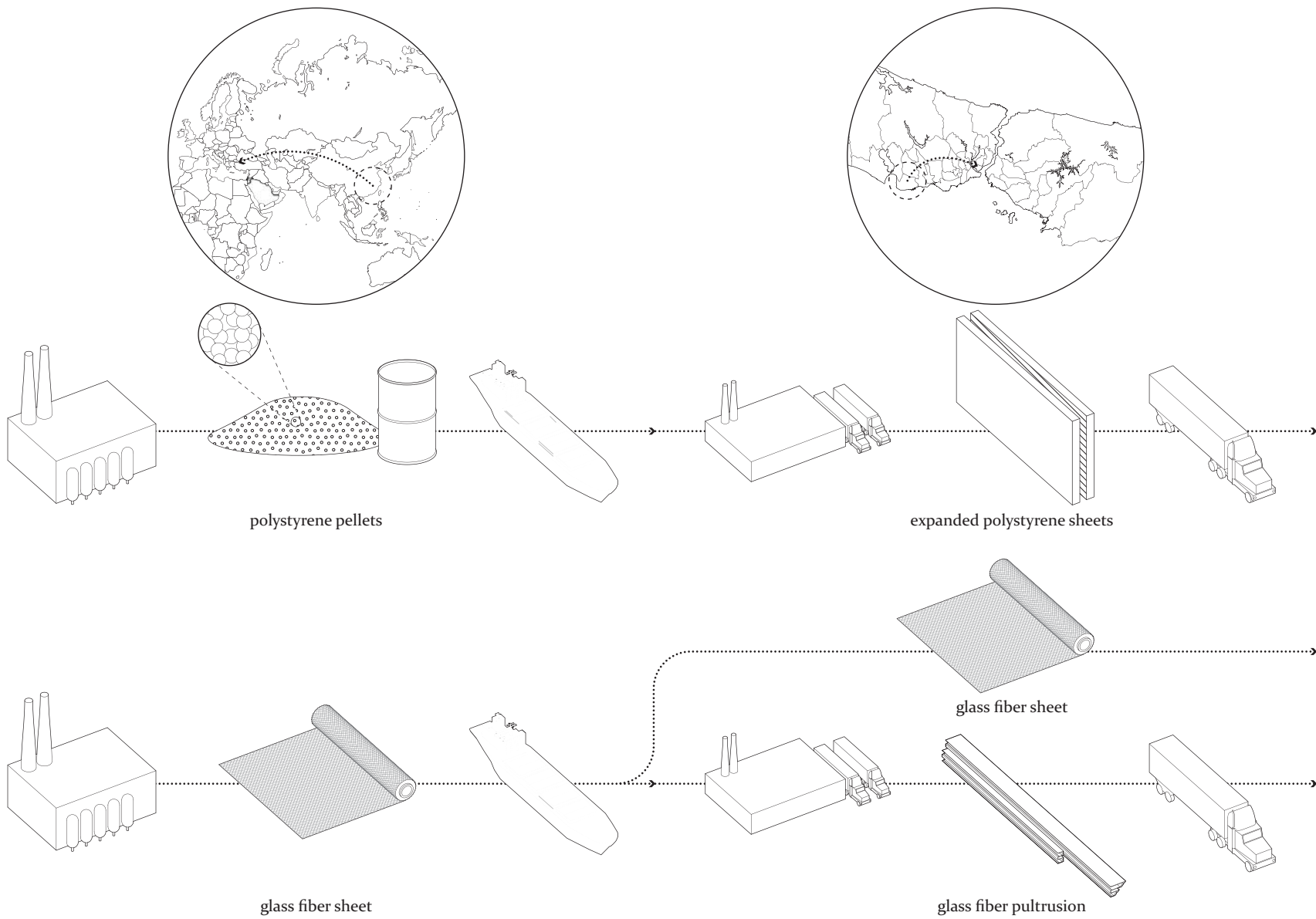


Figure 16: A proposed model of exchanges of property and profits between residents, landlords, and agencies for housing development.





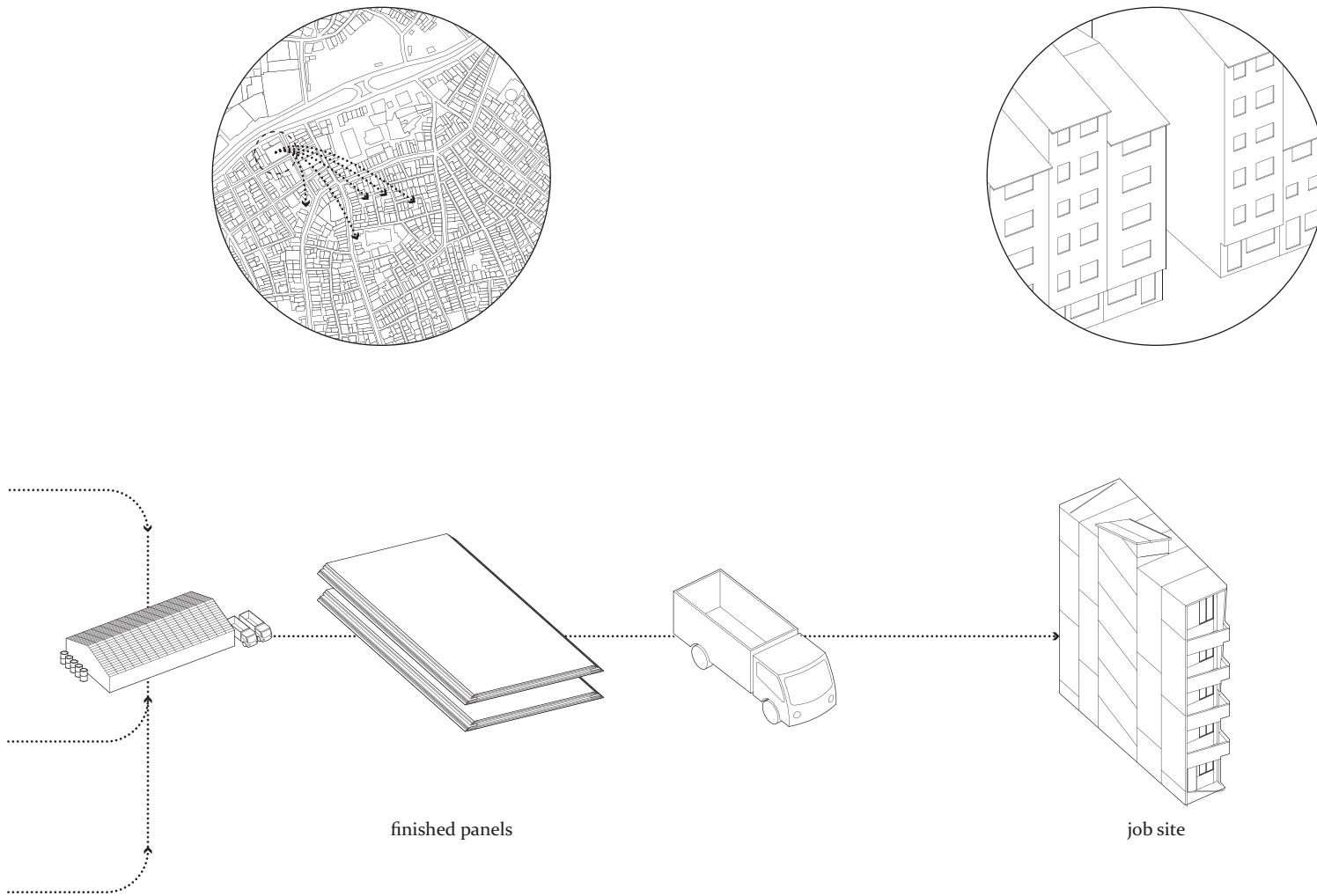


Figure 17: Material flows from global trade to regional manufacturing, to local prefabrication to site assembly.

Component Fabrication Process

This thesis proposes a prefabricated panelized lightweight construction system. The panels produced in these distributed factories would embed all the functional systems of building: structure, weather seal, insulation, fenestration, finish, and conduit for wiring and pipes.

At the heart of this process lies a panel lamination machine (Figure 20)¹. This device would weld two thermoplastic glass fiber sheets to a core material. The composite panel would be light weight and, due to the use of thermoplastics, be almost entirely recyclable. Unlike similar components on the market, such as plywood/polystyrene structural insulated panels (SIPs), these thermoplastic panels may, if properly constructed, require minimal additional finishing after the fabrication process.

First of all, the panels must have embedded, structurally sound joints embedded in them during production. Continuous glass fiber pultrusions of two standard profiles can form the border of the panels and would bond to a laminate skin to be applied later. While this bond is important for transferring structural loads through the skin to the joint and to the next panel, it is also

important to keep a weather seal around the interior foam insulation. Additionally, these channels provide an important aid in the fabrication of the panels themselves.

Indispensable to the ability to produce these panels in large quantities is an effective system for positioning the panels in preparation for cutting. In most non-standard fabrication, registration points have to be milled or marked on an element in order to ensure precise machining of that piece. This process takes time and careful handling in order to not damage the part. In the proposed process, a specially-designed work beds hold panels in place to ease the complicated process of accurately positioning panels relative to the cutting instruments. Guide rails may be located at discrete widths, allowing for a family of panel types to be produced in a single assembly line (Figure 18).

While the panels may embed the key systems of a building volume within their widths, simply pushing expanded polystyrene sheets through the lamination machine would result in another industrially standardized product on the market no different than traditional SIPs. Each panel would have to undergo cutting to fit within a given site, and then joined to its neighbors so as to maintain the integrity of those embedded systems. Such labor, whether undertaken in a factory as a prefabrication step, or on site, would frus-

¹ For a more thorough technical explanation of this process, see Borazghi, Hossein. Process and Machine for Producing Lightweight Thermoplastic Composite Products in a Continuous Manner. US: Patent 7429305. 30 September 2008.

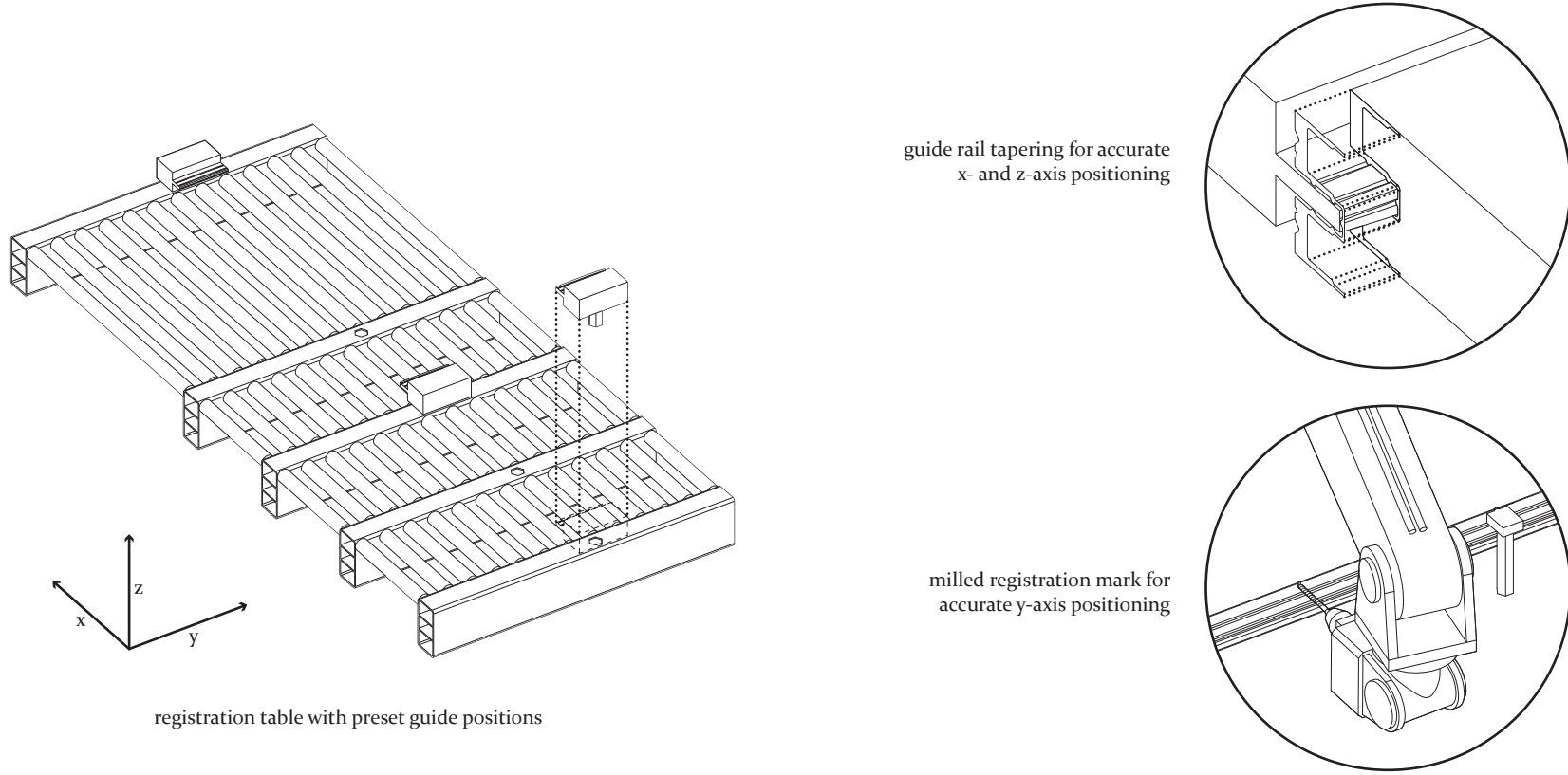


Figure 18: Registration of parts in assembly process.

trate any effort to employ local, unskilled labor in the production process.

By confining the nonstandard operations on panels to cuts along their ends, the production of elements with varying geometries is possible. Furthermore, by reducing the number of nonstandard

operations, the speed of production is also increased and would not impeded the efficiency of the continuous feed process of the lamination machine. This fabrication procedure, illustrated in the following pages (Figures 19,21, 22,23), can provide the interior and exterior panels for a new housing type.

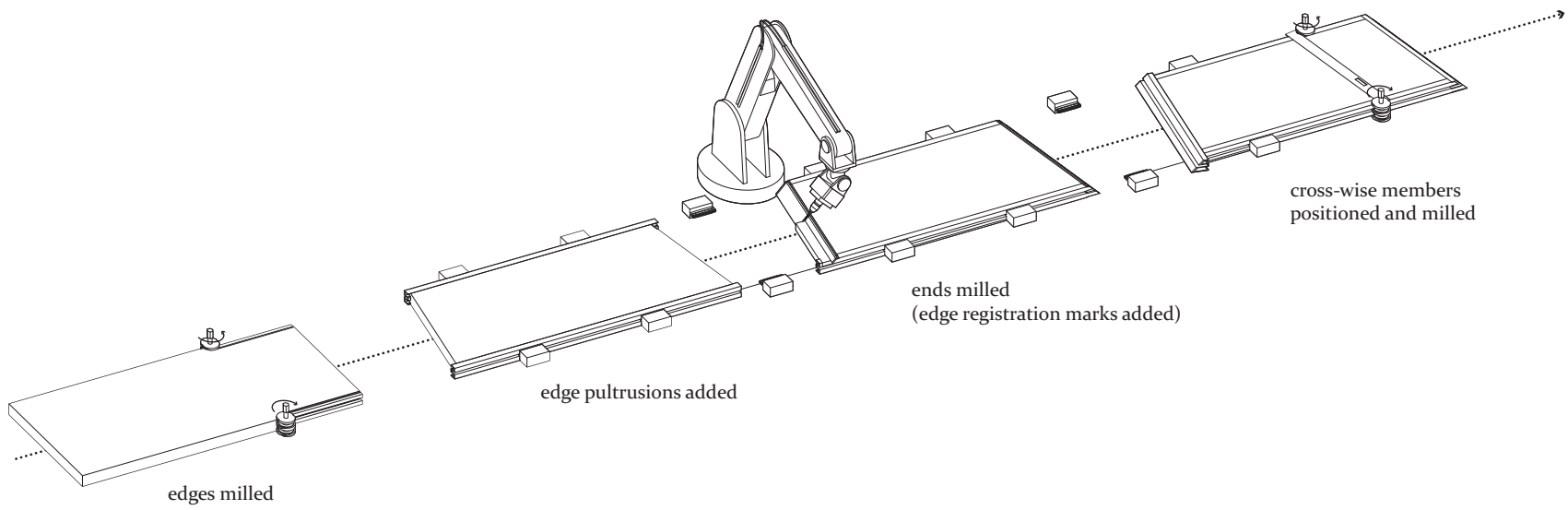


Figure 19: Initial milling and edging of panels.

Figure 20: Diagrammatic section of panel lamination machine.

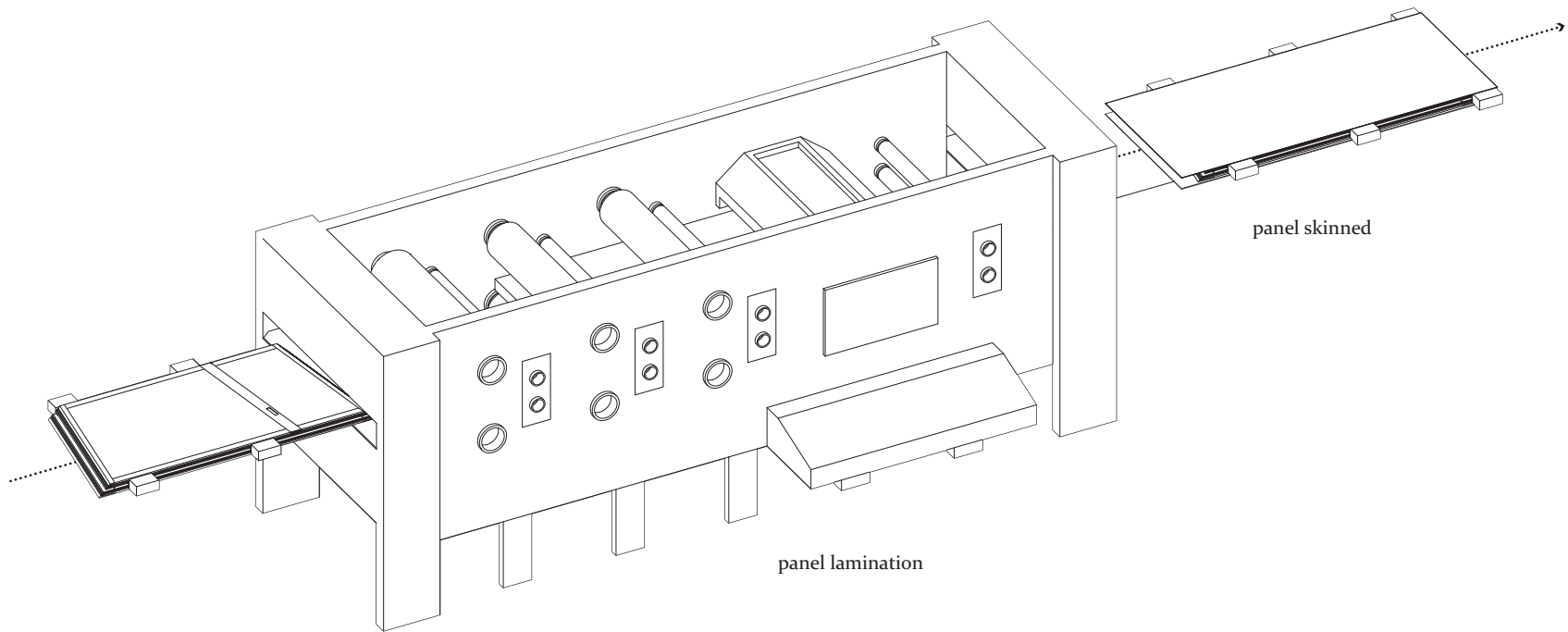
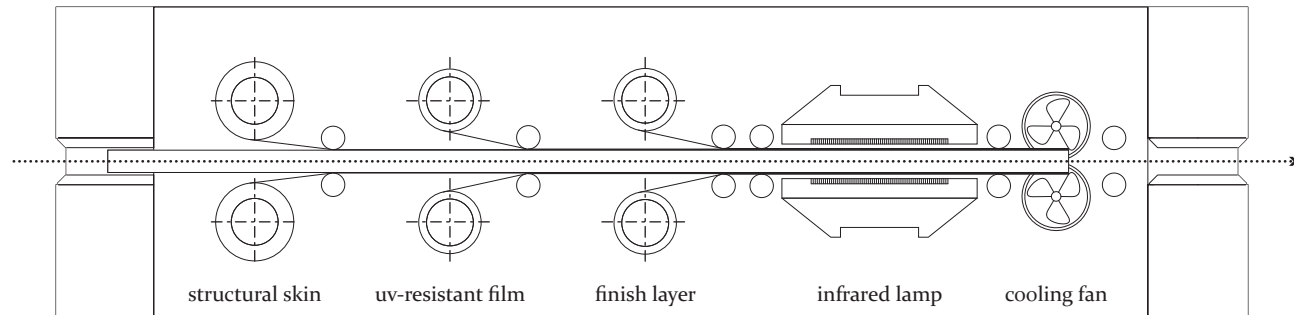


Figure 21: Lamination of panels.

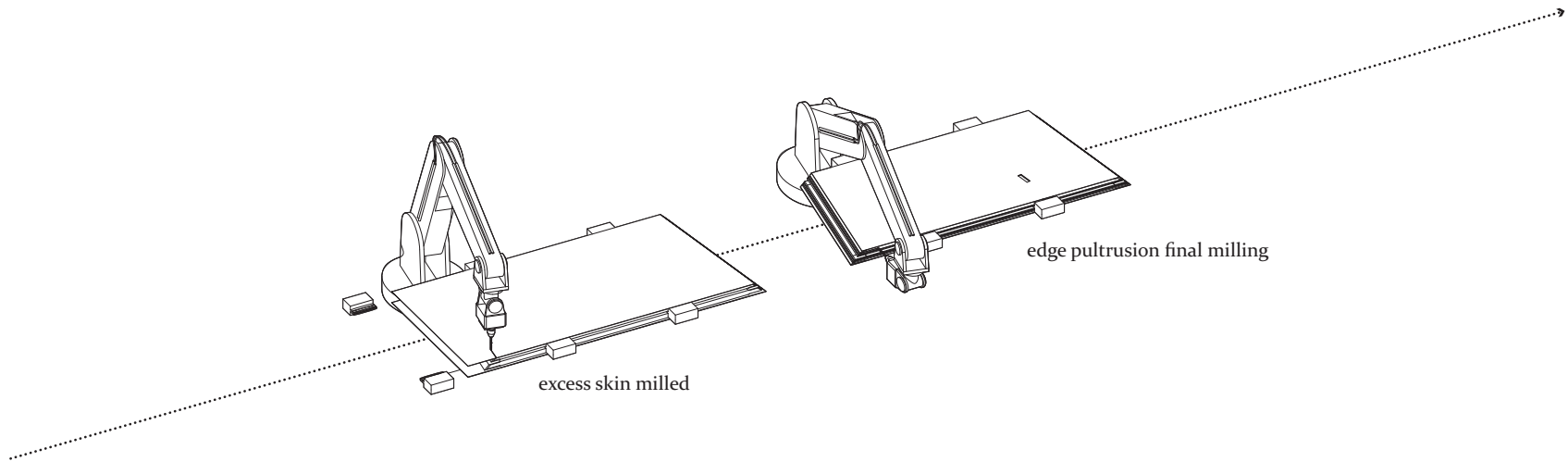


Figure 22: Remilling panel edges after lamination.

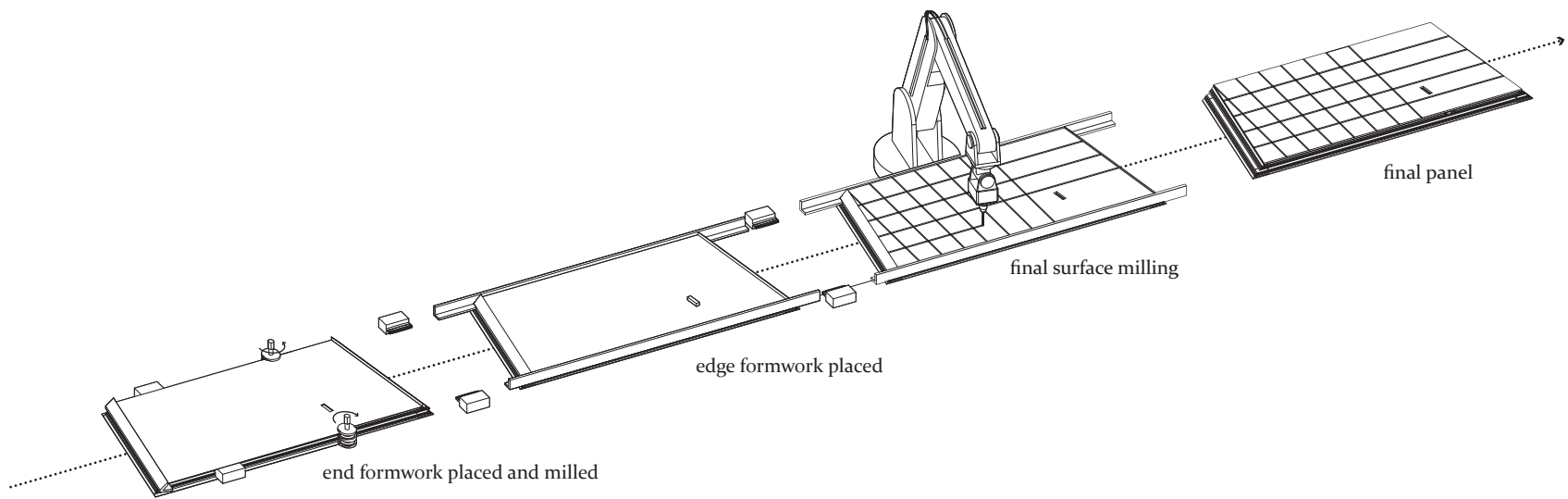
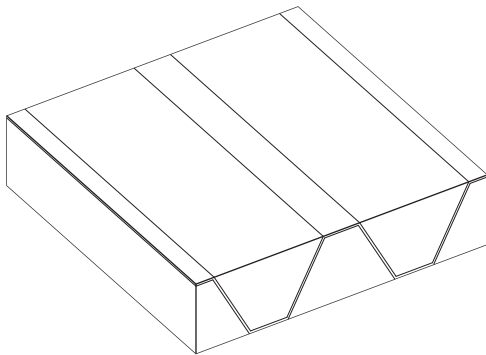
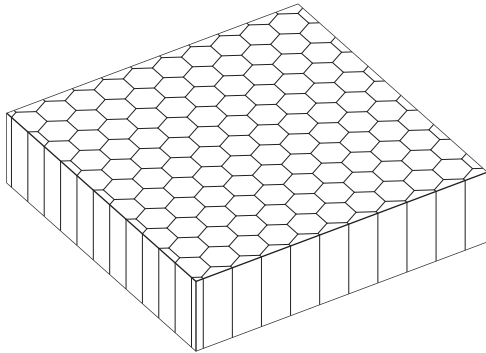
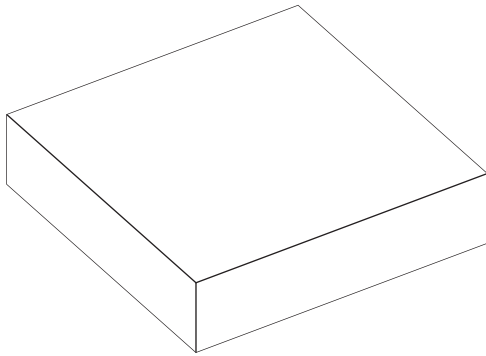


Figure 23: Placing edges and pouring and milling finish surface.



The production process allows for more detailed specifications of the materials used in different projects, or even in different panels within the same process. For instance, these specifications can better tune panel cores to their unique structural requirements. Core materials can range from expanded polystyrene, which carries virtually no load on its own, to foam-infused honeycomb, which adds stiffness to longer panels, to foam-infused corrugated panels, which will carry significant loads across longer spans (Figure 24).

Figure 24: Core material options.

Likewise, the structural skins may be swapped out, albeit at the cost of slowing production down slightly (Figure 25). The changing of skin material requires one to remove and reload the rolls on the laminating machine. Of course, the panels of a project with similar structural skins could be grouped during the production phase, limiting the lag time.

The fabrics that make up the structure of the panel are typically of bi-directional woven glass fiber. Panels may require, however, a unidirectional fiber pattern to take higher loads from one direction, or, alternatively, may use weaker panels made from recycled, non-oriented shorter strands of fiberglass.

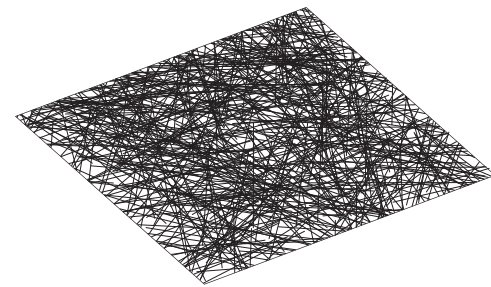
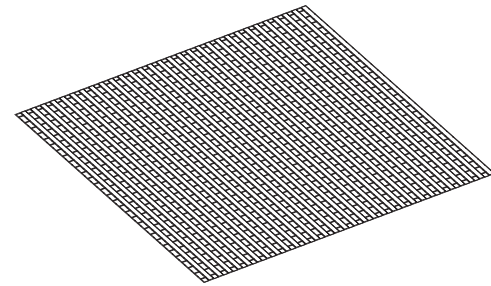
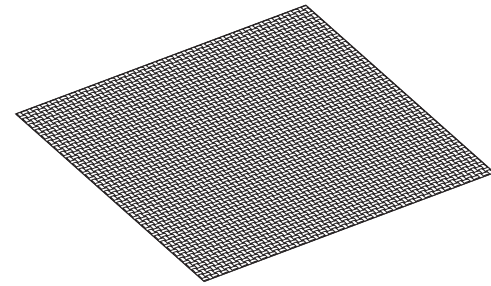
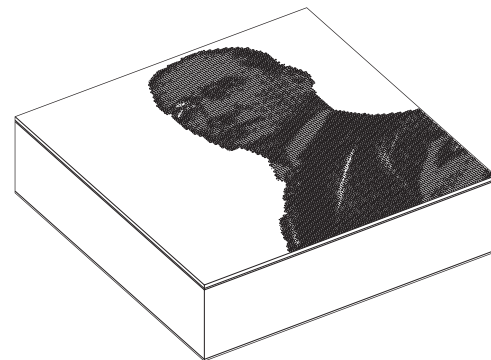
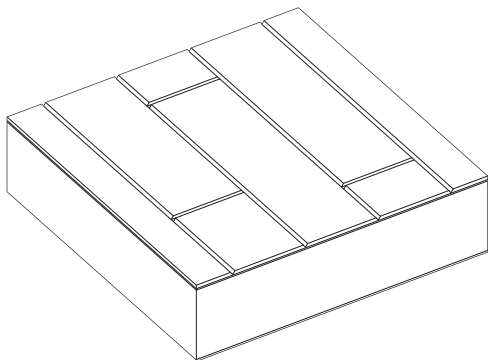
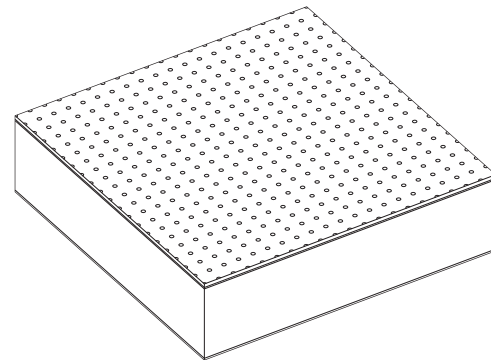
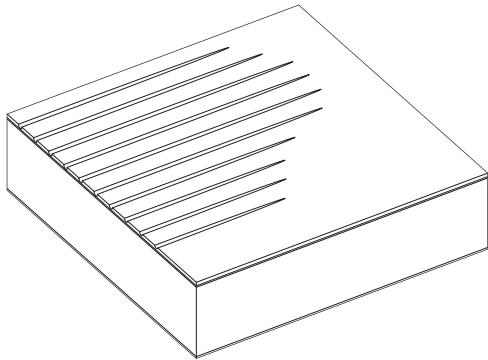
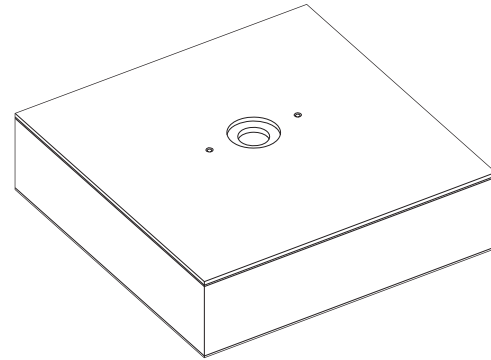
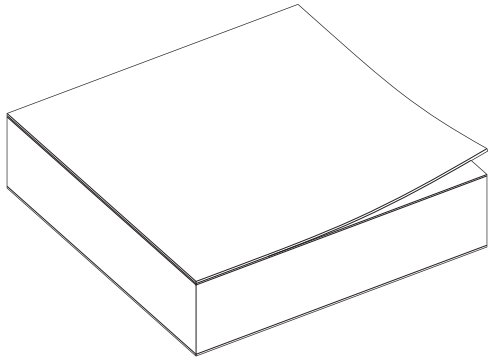


Figure 25: Skin material options.



Finishes, too, may be automated as part of the production process (Figure 26). These exterior layers of the panels are required to be wearing surfaces to protect the structural skins underneath. This coating may be as thin as a veneer, which can be loaded into the lamination machine or may be thicker glued panels, like finish-grade plywood, or cast materials such as cements.

The later, thicker finishes may be milled to better accomplish performance goals. Milling instructions may create penetrations to conduits of pipe or wire to allow installers to directly attach fixtures to the panels. They may also create drainage channels in panels or even allow for the direct casting and milling of certain fixtures like shower basins. Acoustical dimpling may be milled into softer materials to better absorb sound.

These finishes may also have aesthetic finishes placed in them as well. Grooves may simulate parquet or hardwood flooring patterns for aesthetic reasons or may even hide joints between adjacent panels. Decorative patterns may be milled into surfaces as well, opening up a wide range of design possibilities for interiors.

Figure 26: Finish material and milling possibilities.

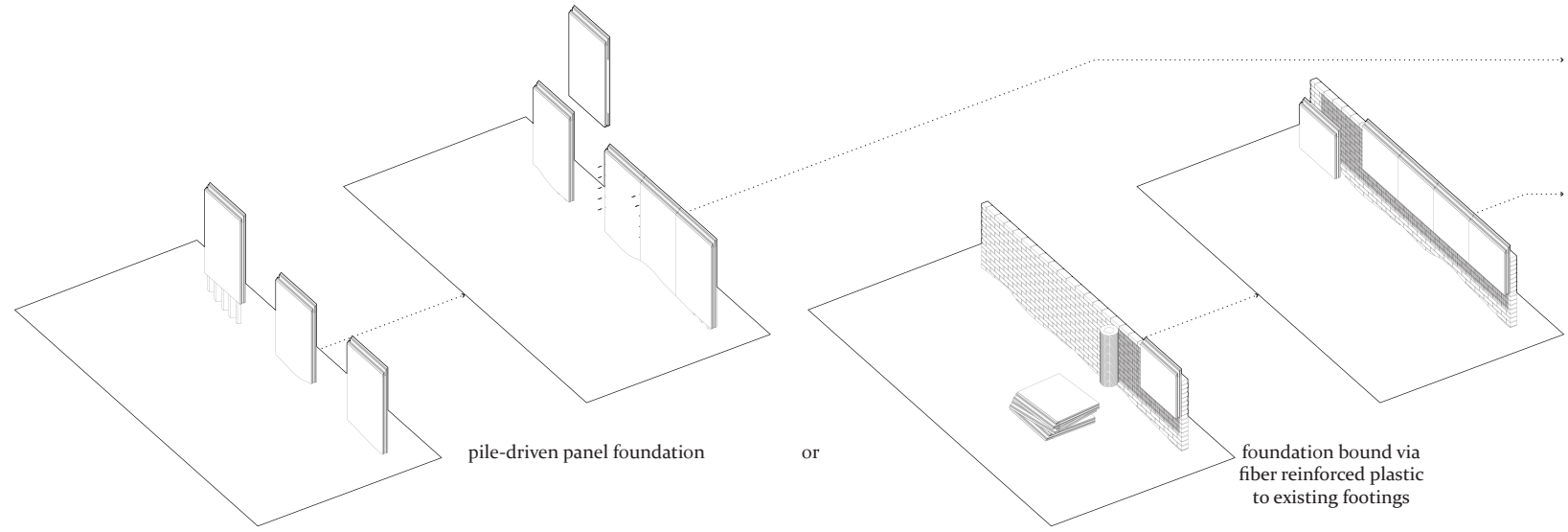
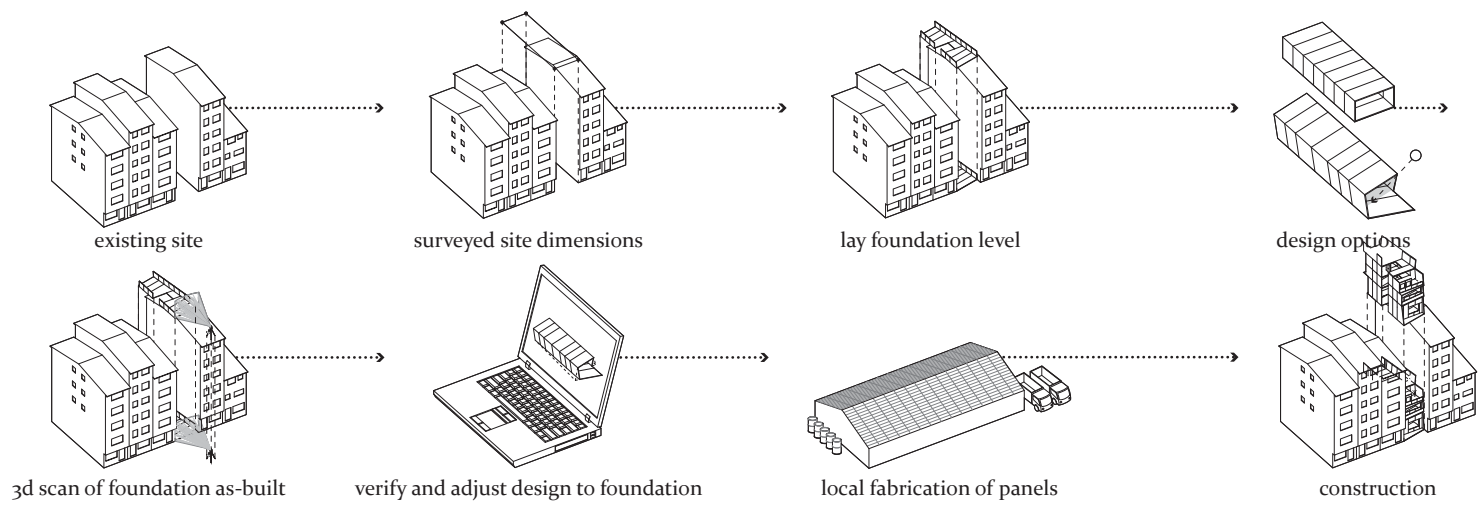
Figure 27: General process for design and construction.

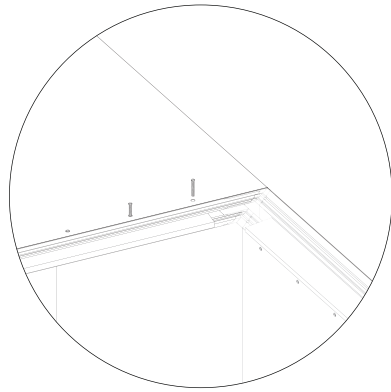
Construction System

Once the panels are produced, the erection of a building would be quick. Parts are delivered to site as they are needed. By configuring panels with continuous joints around corners, attaching panels to one another becomes easier. Connections between panels are made with screws placed through milled pilot holes through fabricated biscuit elements. Conduits which carry wires and pipes would also connect. For details of joints types, see Appendix II.

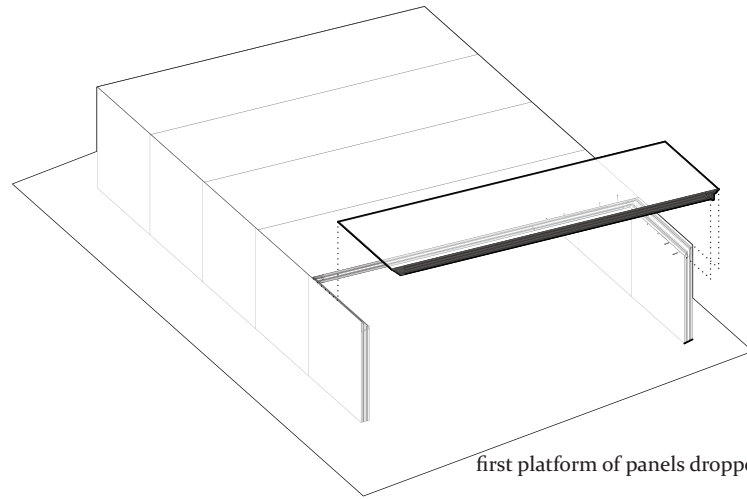
As the fabrication procedure makes panels that are highly accurate, design work would proceed first with the laying of a foundation course of panels before producing the final set of fabrication instructions (Figure 27). However, after this, all panels should align to one another with extremely tight tolerances. The flexibility of the panels themselves helps in the construction process as well. The following pages show the basic construction process of a stacked unit structure (Figures 28, 29, 30).

Figure 28: Foundation types.

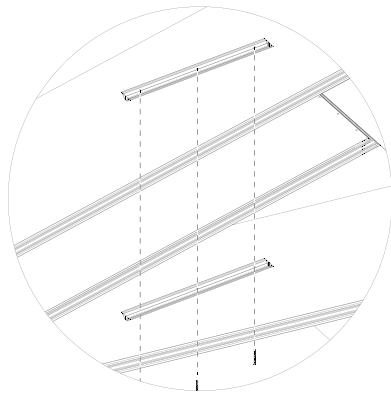




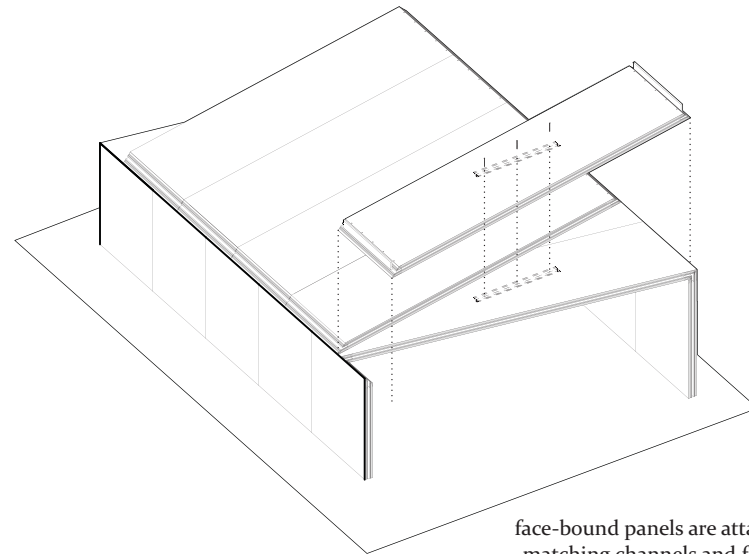
fasteners join biscuits to two sides



first platform of panels dropped into place

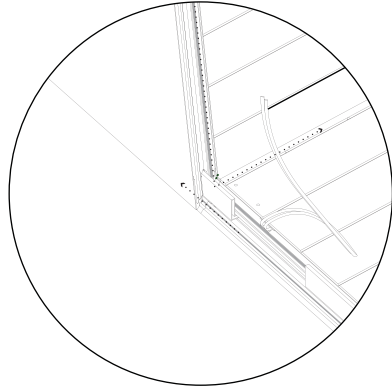


subsequent floors may bind the panels via fasteners from below

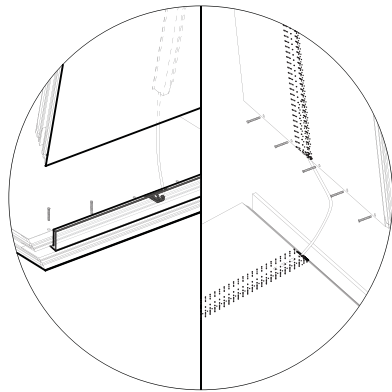


face-bound panels are attached via matching channels and fasteners

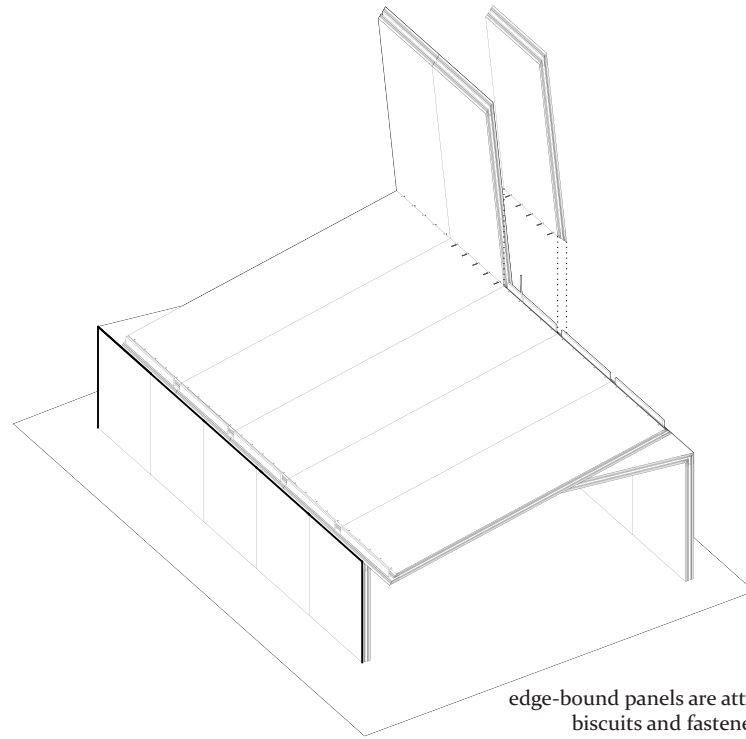
Figure 29: Placement and fastening of floor panels.



outer gaskets continuous across gaps between adjacent floor plates (longitudinal lines)
 inner gaskets continuous across floor and wall joints (lateral lines)



electrical wires are run through connections from
 floor to wall panels and then to ceiling panels



edge-bound panels are attached via
 biscuits and fasteners

Figure 30: Placement and fastening of wall panels.

İstanbul on the Ground

By looking at a few representative communities from İstanbul, a clearer picture of the housing needs of the city emerges. This project examined three areas in particular. The first, comprising the neighborhoods of Fener and Balat, is located in the Old City. The second, in the New District, yet cut off from the more tourist-friendly area surrounding İstiklal Caddesi and adjacent to Taksim Square, is Tarlabası. Finally, north of the inner ring highway is Kuştepe, a newer area settled during the 20th century.

Each of these communities is in or relatively close to the city's center and, as a result of their locations, their residents are under growing pressure from the city and developers to relocate. As of 2010, some such projects have already been executed. Residents frequently face uncertainty as news of planning proposals are spread by word of mouth and then rescinded. In the words of one landlord in Tarlabası, "We are waiting, but we don't know what for" (Akarsu and Aktaş).

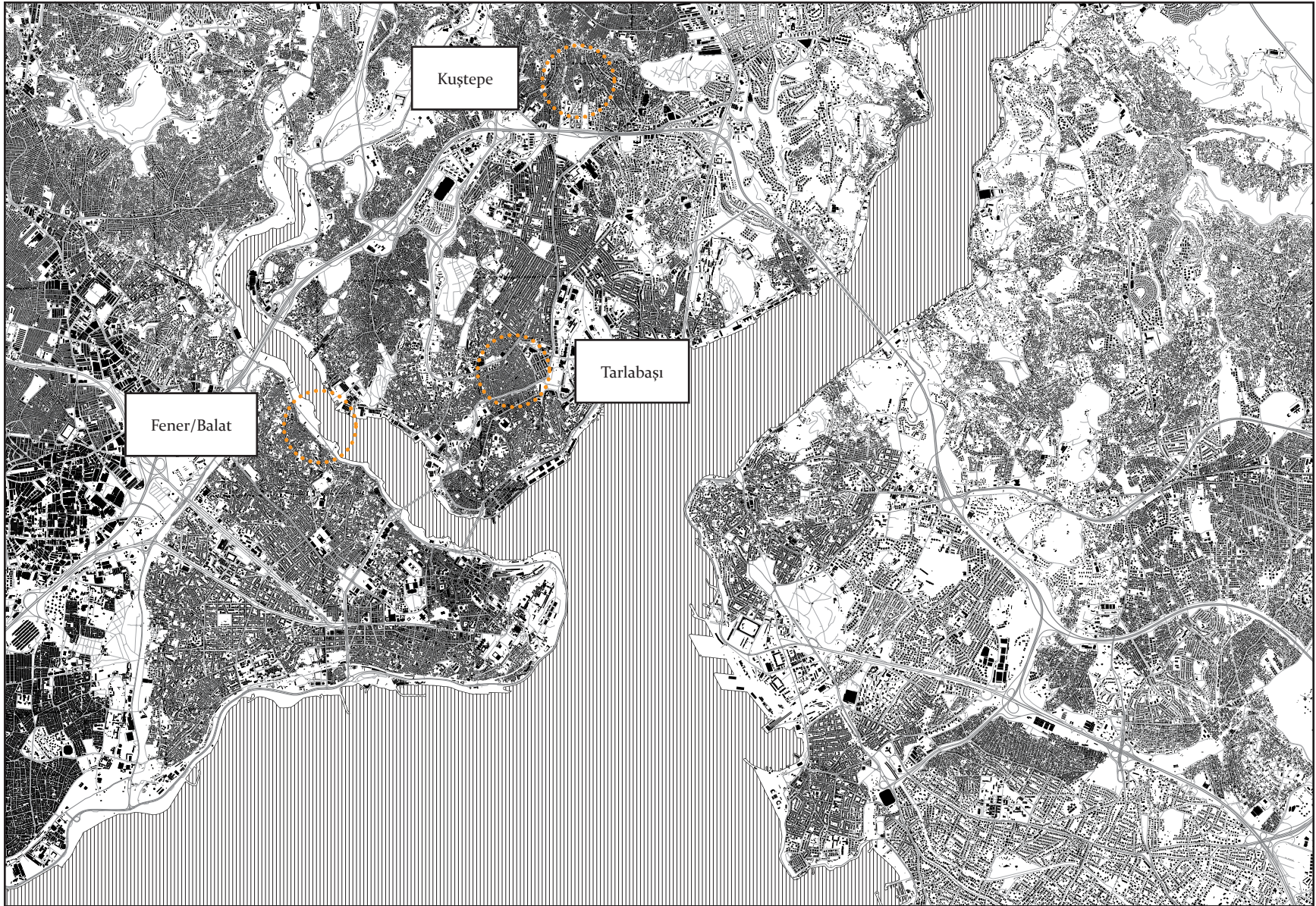


Figure 31: Locations of neighborhood site analysis.

Site I: Fener/Balat In İstanbul, Fener and Balat are the traditional homes of the Greek Orthodox and Jewish communities, respectively. These two neighborhoods are near the northwest corner of the Fatih District, also known as the Old City, the peninsula which sits between the Golden Horn, the Sea of Marmara, and the Bosphorus Strait. Settled early in İstanbul's history, this district nonetheless features some of the European-style wooden houses from the 19th century. Although the Greek Orthodox Church maintains a significant presence here, the area has been largely resettled and is currently undergoing targeted redevelopment with government assistance.

Running along the Golden Horn is a highway and park. This replaced old industrial and port infrastructure. Nearest to this street are a few older roads with very small building plots between them. Many of the structures found here are dilapidated and condemned. As one moves farther away from the water, the street pattern is more regular and buildings are newer. Here, however, there are still several empty plots as well as shorter structures that can potentially be redeveloped.

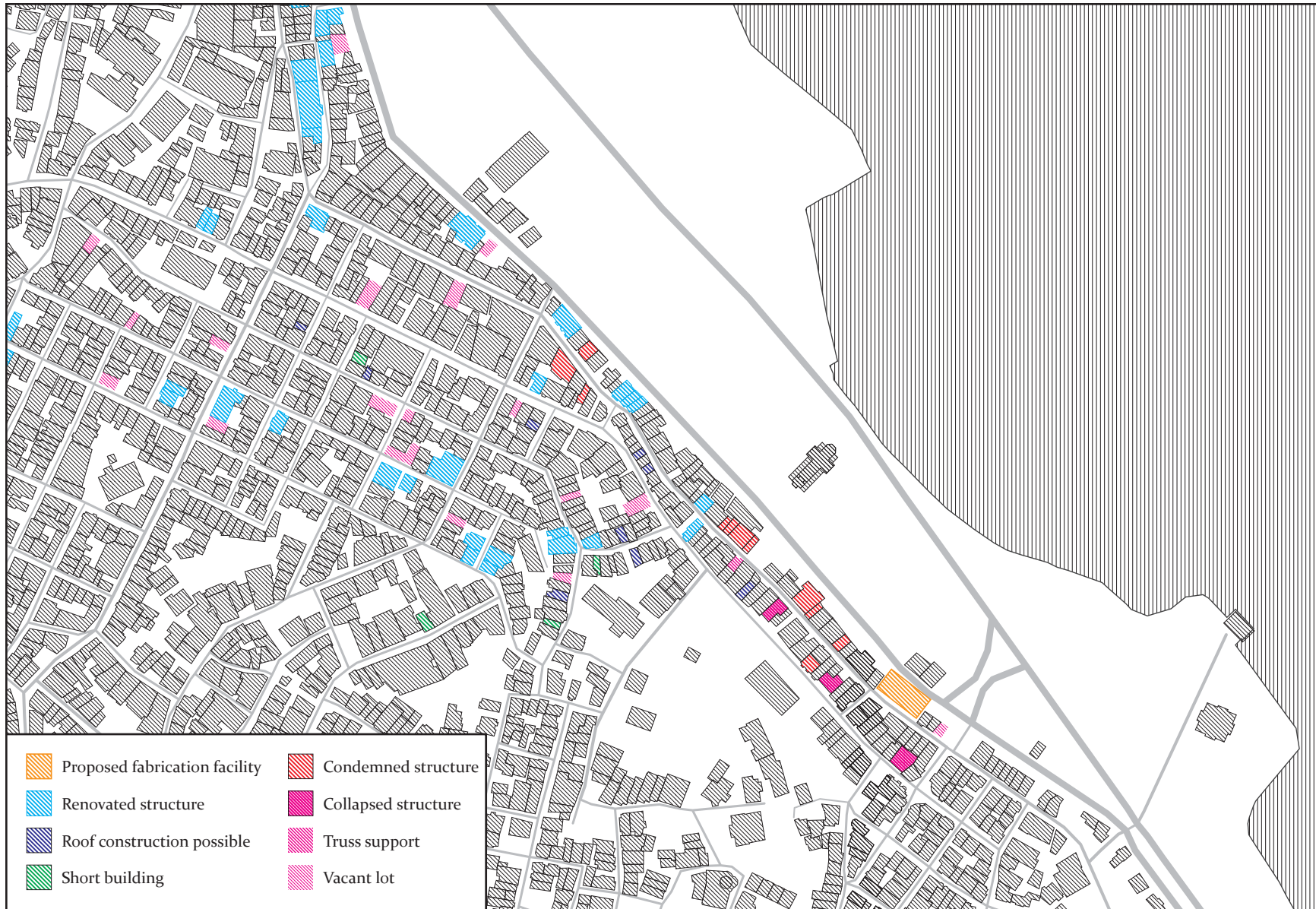


Figure 32: Fener/Balat site map..



Figure 33: Partially collapsed buildings.



Figure 34: Short building.



Figure 35: Collapsed and condemned buildings.



Figure 36: Renovated houses.

Site II: Tarlabası Tarlabası is a community located to the northwest of Taksim Square in Beyoğlu. Like the communities in the New District, Tarlabası has a mix of older, 19th century wooden houses and postwar apartmanlar. A few very old gecekondular exist, but these often predate the population boom of İstanbul. The community is highly varied: recent immigrants in search for cheap housing near the city center, older landlords, minority groups like the Roma, students, and transvestites. The expansion of Tarlabası Bulvarı to the community's south in the 1980s cut the area off from the tourist district surrounding İstiklal Caddesi. Recent redevelopment proposals have increased anxiety within the community and protests are commonplace.

As one walks north from Tarlabası Bulvarı, the ground slopes downhill. Buildings sizes vary depending on the street, with shallower sloping streets divided into the 5 meter plot width and steeper ones often having irregularly shaped buildings. Some older structures have footprints taking up several adjacent lots. The shifting populations and low rents have resulted in the poor maintenance of the neighborhood's buildings. As a result, buildings that are partially or completely collapsed are common. Frequently, in areas built up using shared partition walls, trusses are erected to support buildings whose neighbors have been demolished.



Figure 37: Tarlabası site map..



Figure 38: Trusses supporting partition walls.
68



Figure 39: Collapsed building.

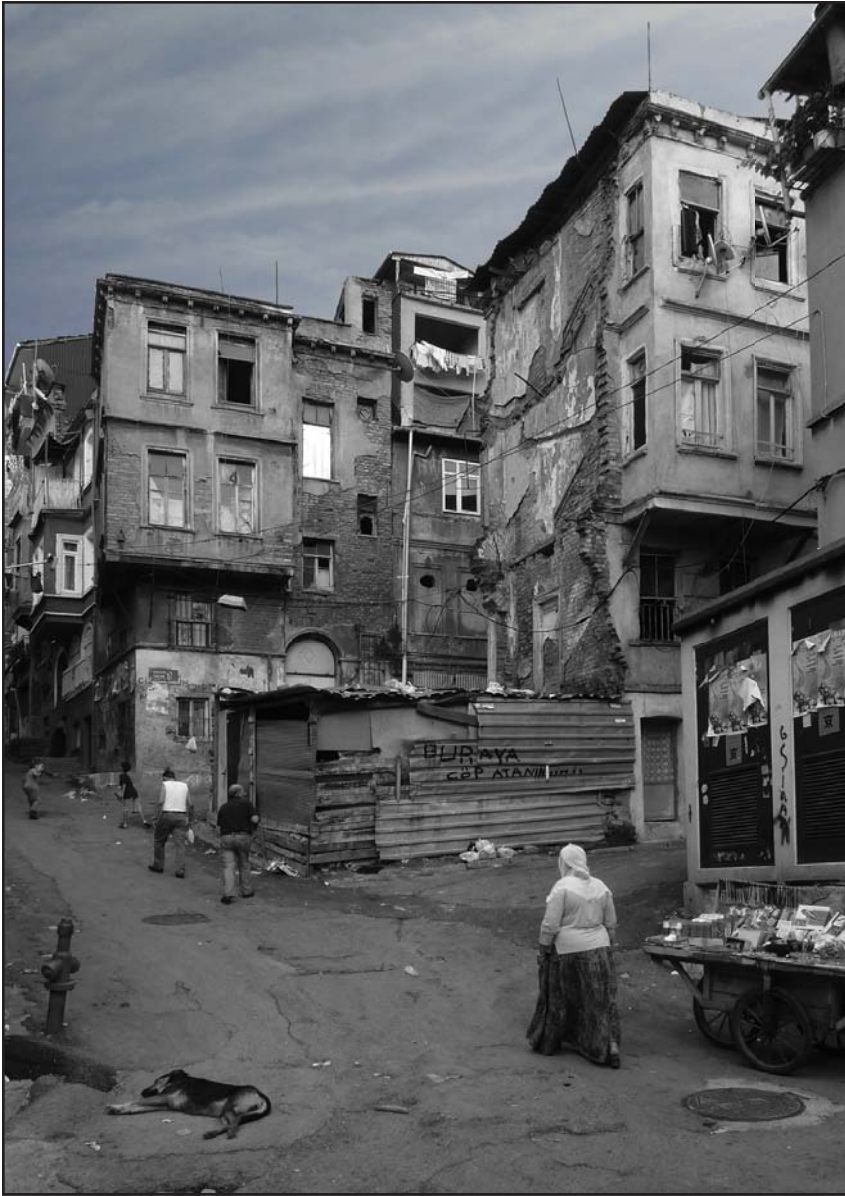


Figure 40: Dilapidated single-storey structure.



Figure 41: Collapsed building.

Site III: Kuştepe Kuştepe is a hilltop within the Şişli district of İstanbul. The area is a former gecekondu settlement just outside the 19th century city boundaries. Today, it sits north of the inner ring highway. The community has been partially redeveloped: Bilgi Üniversitesi has a campus at the hill's summit and new developments, most spectacularly the new Trump Towers, are encroaching from the highway northward. The area is built up with apartmanlar, but still has many surviving gecekondu from original settlers of the area. Kuştepe is a hill and streets roughly follow the contours of the slope, which is extremely steep.

The majority of construction are apartmanlar in the typical 5-7 m width. The buildings are either built with slabs spanning between structural partition walls if running along a contour street or are concrete frame buildings — with columns and hollow brick infill — on larger sites within the slope. As with the majority of newer neighborhoods, buildings here were built one at a time, so shared partition walls are rare. Similarly, building height varies greatly and well-upgraded gecekondu are still found within the streetscape. As with the other neighborhoods examined, Kuştepe has its share of collapsed or deteriorating structures, although official condemnations are rare.

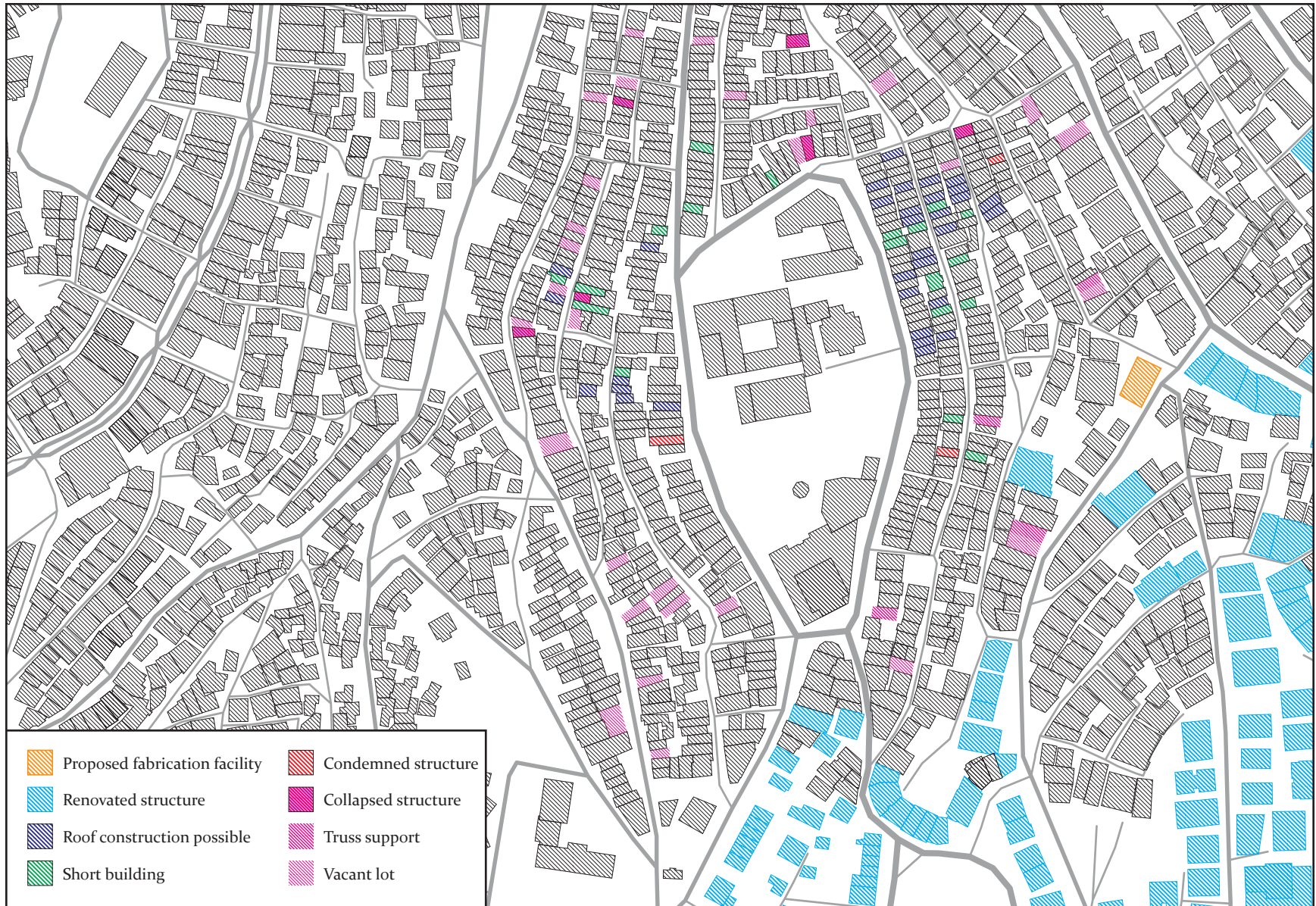


Figure 42: Kuştepe site map..



Figure 43: Partially collapsed structure.



Figure 44: Collapsed building.



Figure 45: Streetscape.



Figure 46: Apartmanlar of varying heights.

Dormitory Apartman

The first prototype is designed to be deployed on a small scale site and is built to be as cheap as possible. Typically imagined for social housing, the dormitory apartman is constructed from a single exterior shell with a stair core that provides shear strength for the entire building. Shared facilities, such as kitchen, eating, and living facilities are located on the bottom floor. Individual bedrooms of various sizes are located at the floors above with bathrooms on every other floor.

The single panel floors limit the width of the building to about 4 m, but may be allow for larger widths if stronger, more expensive core materials are used. The shell exterior structure may serve to buttress adjacent buildings, providing them with additional stability if they are attached via FRP or another anchoring system.

Figure 47: Axonometric views of Dormitory Apartman model.

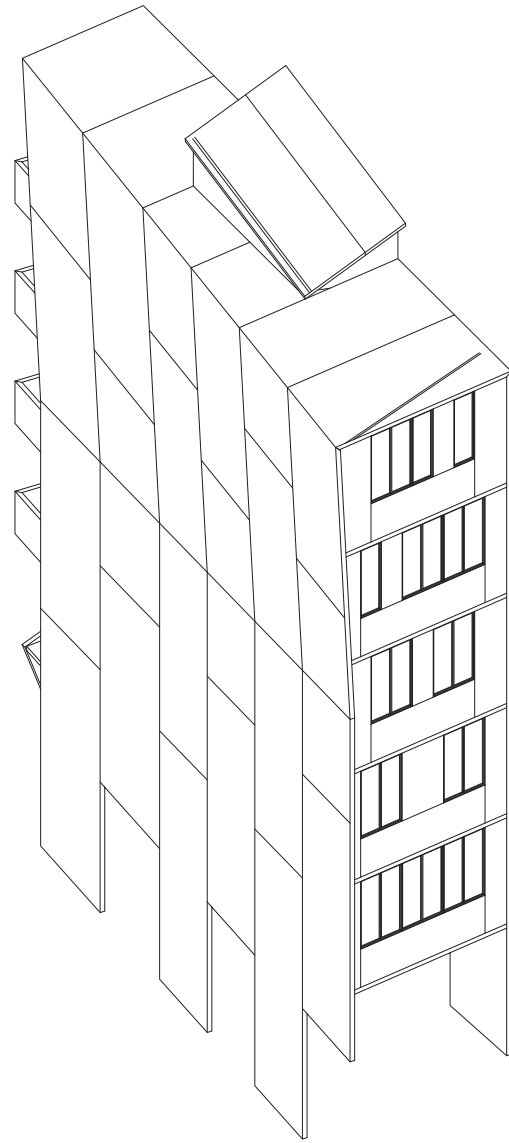


Figure 48:
Representative plans of
Dormitory Apartman
Scale: 1:100

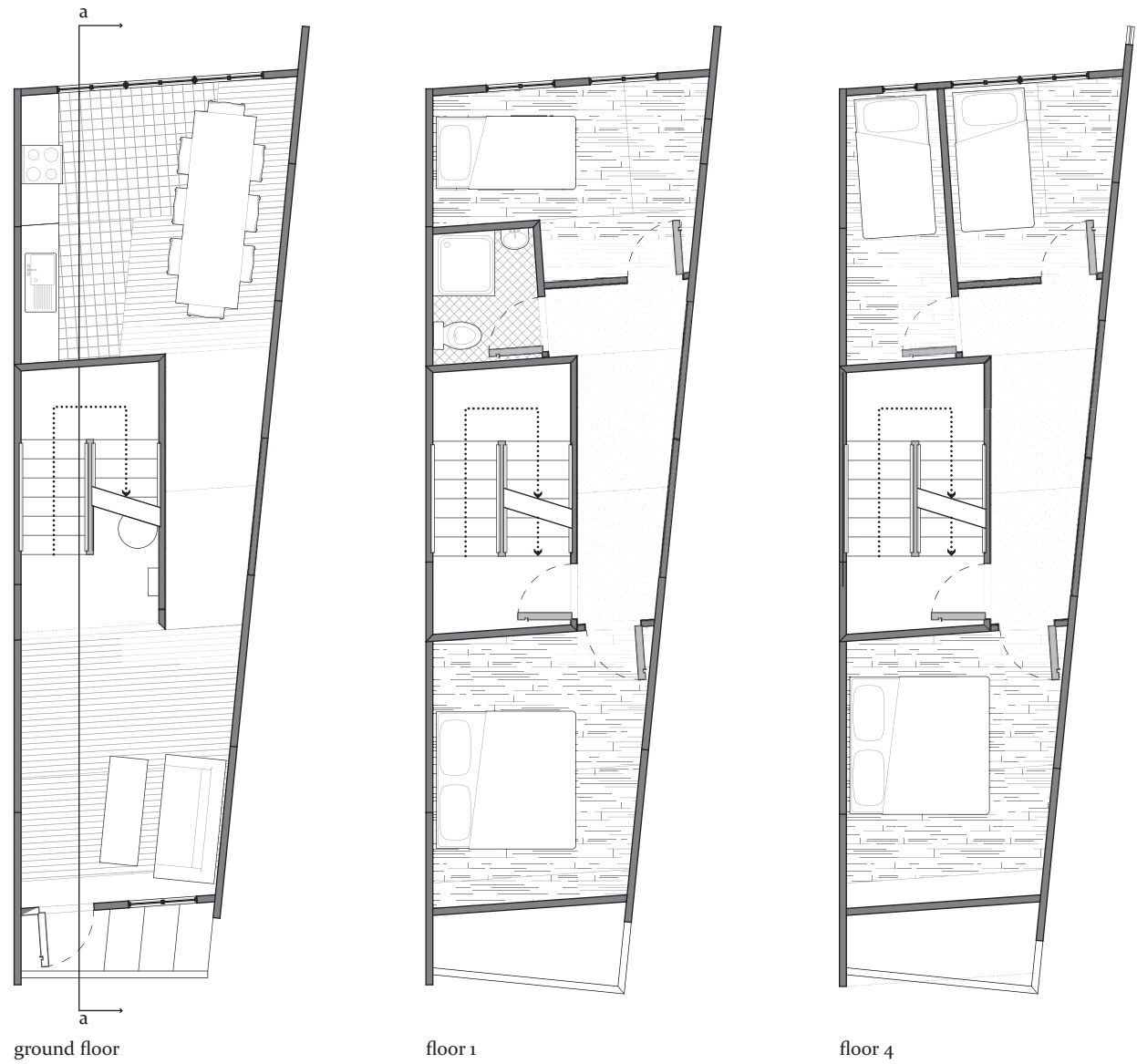


Figure 49:
Section aa of
Dormitory Apartman
Scale: 1:100

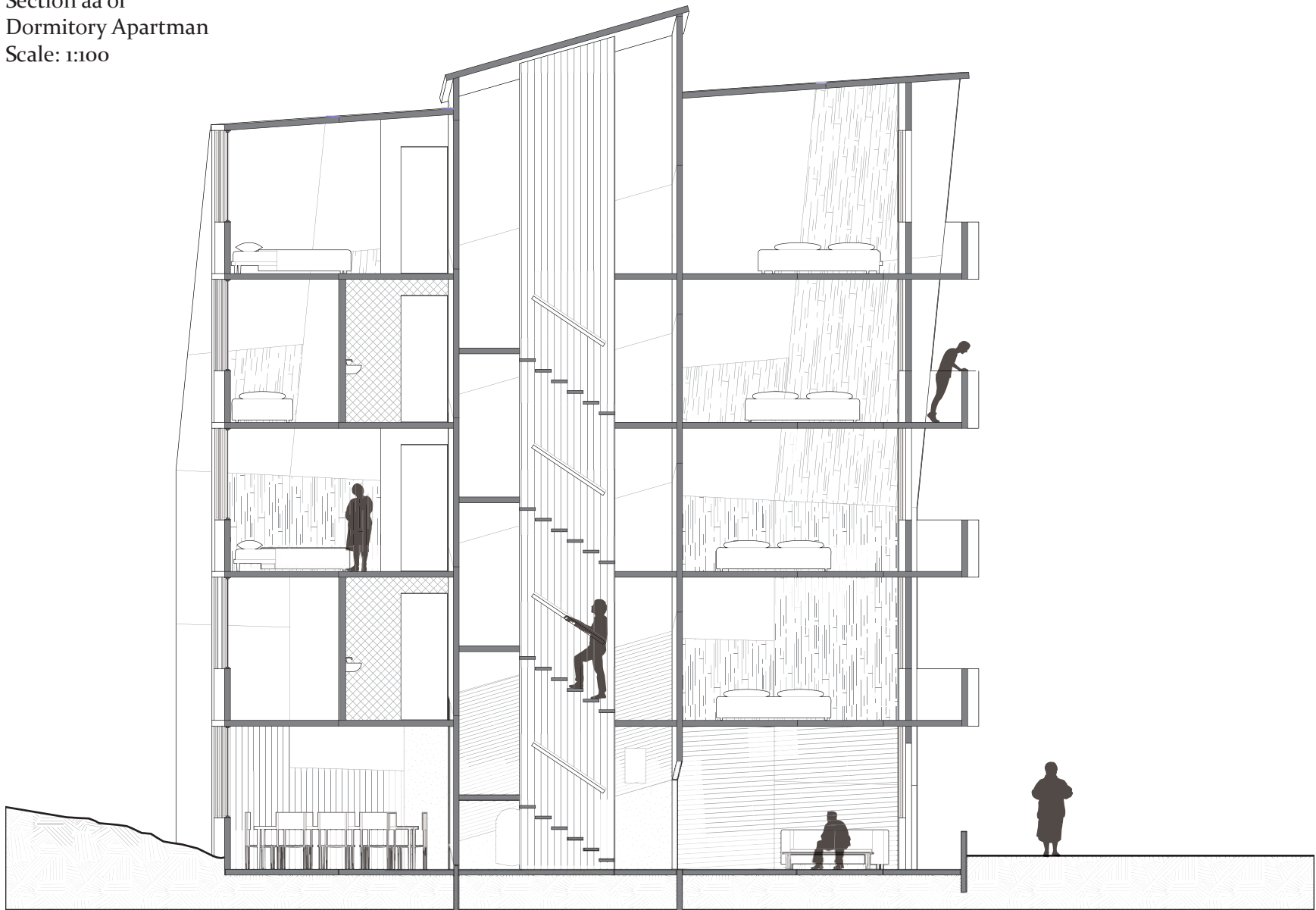




Figure 50: Exterior perspective of Dormitory Apartman in Fener/Balat.

Figure 51: Interior ground floor perspective in Dormitory Apartman.



Stacked Unit Apartment

The second prototype is intended for larger building sites. Rather than a single shell that supports the smaller floors in between, this model is a series of stacked apartments. A notch in each shell accommodates a staircase and lightwell which carry electricity and water supply and return pipes to each unit.

The stacking of units atop one another allows for increased spans and more individual design freedom for interiors. Rather than a collective clientele, this apartment system allows for individual designers (occupants or landlords) to have control over unit layout and finishes. Units may even be taller or shorter depending on preference and budget, including maisonette units for larger families. Zoning regulations and basic design rules constrain some of the customization options so that cantilevers do not shade lower units too much or stick too far over the street.

The structural characteristics of the panelized shell system also allow for interiors to be reconfigured. Walls may be removed and replaced with new walls from the panel system, or may be finished using other means.

Figure 52: Axonometric views of Dormitory Apartment model.

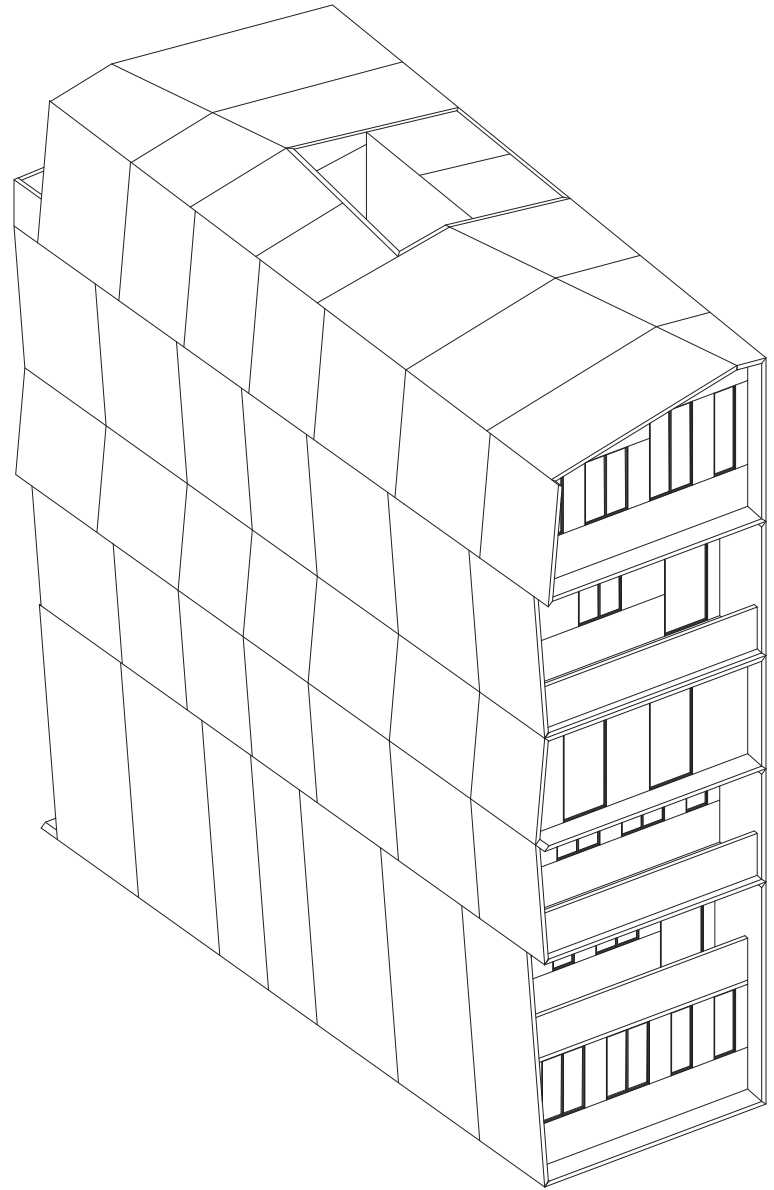
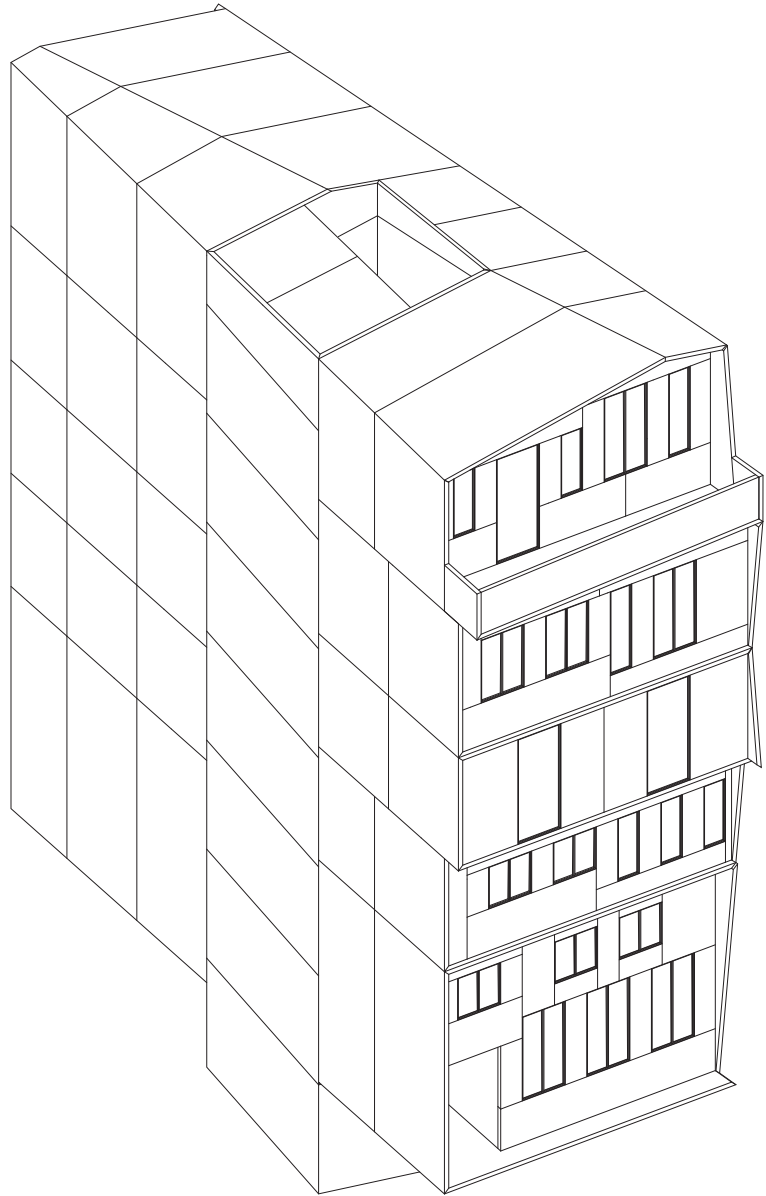
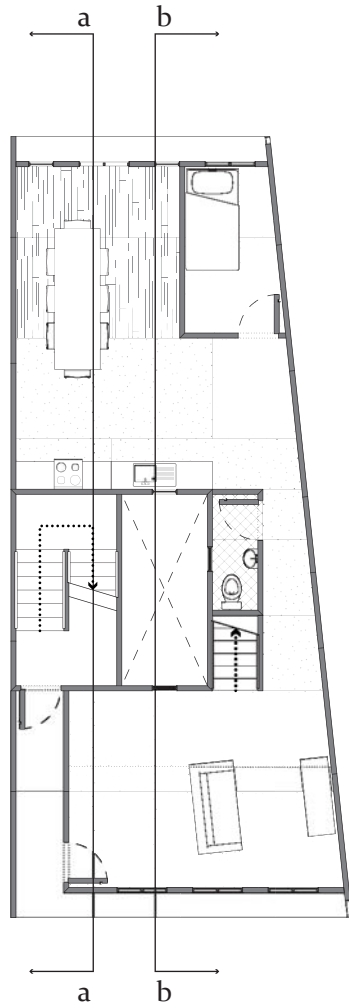
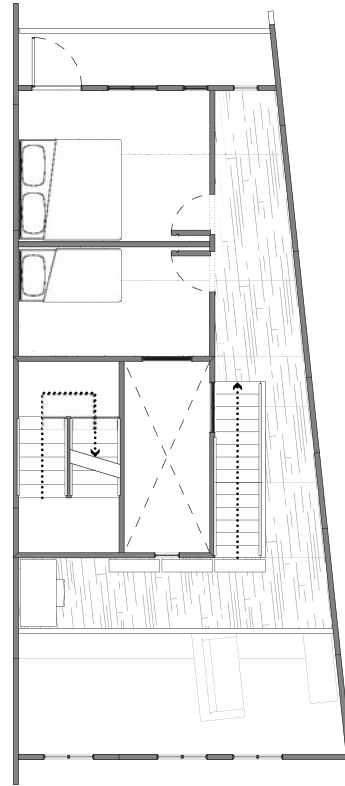


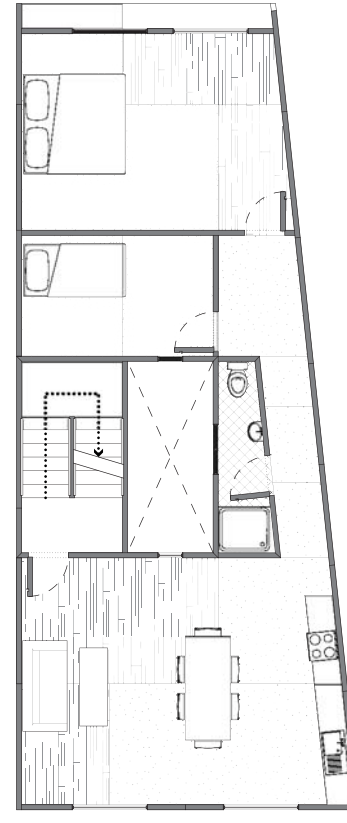
Figure 53:
 Representative plans of
 Stacked Unit Apartman
 Scale: 1:150



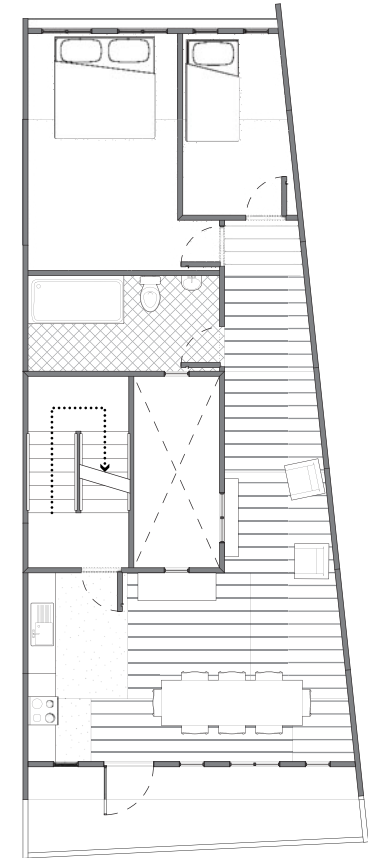
ground floor
 (maisonette unit)



floor 1
 (maisonette unit)



floor 3



floor 5

Figure 54:
Section aa of
Stacked Unit Apartman
Scale: 1:200

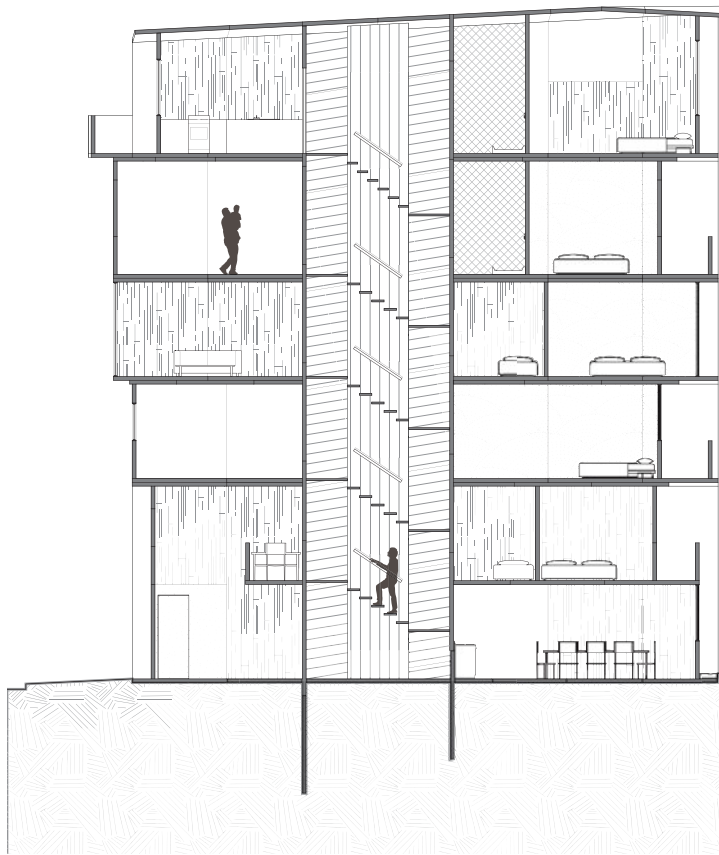


Figure 55:
Section bb of
Stacked Unit Apartman
Scale: 1:200





Figure 56: Exterior perspective of Stacked Unit Apartman in Kuştepe.

Figure 57: Exterior perspective of Stacked Unit Apartman in Kuştepe.



Single Unit Apartmanlar

These units are built on various smaller sites throughout the urban fabric. Most commonly, a unit may be placed on top of an existing structure. The lightweight nature of the panels allows these units to bear on the building without requiring additional reinforcement. The unit would add tenants to an existing building, which, in turn, would mitigate rent increases. Furthermore, the higher quality of construction of this additional floor would serve as an improved roof for the building below. By being better able to shed water than the previous construction, the additional unit increases the lifespan of the structure as a whole.

Units may also bridge between taller structures on either side of a shorter building. One possible intervention would allow tenants of small gecekondular to rent air rights above their homes to landlords of buildings on either side. The rent paid by tenants of these new units would be paid to the gecekondur resident below and the adjacent buildings that support it both in terms of providing circulation and structure. In return, the bridge unit would prevent excessive damage to the gecekondur below in an earthquake and even help support the walls it bears on.

Figure 58: Axonometric views of rooftop Single Unit Apartman.

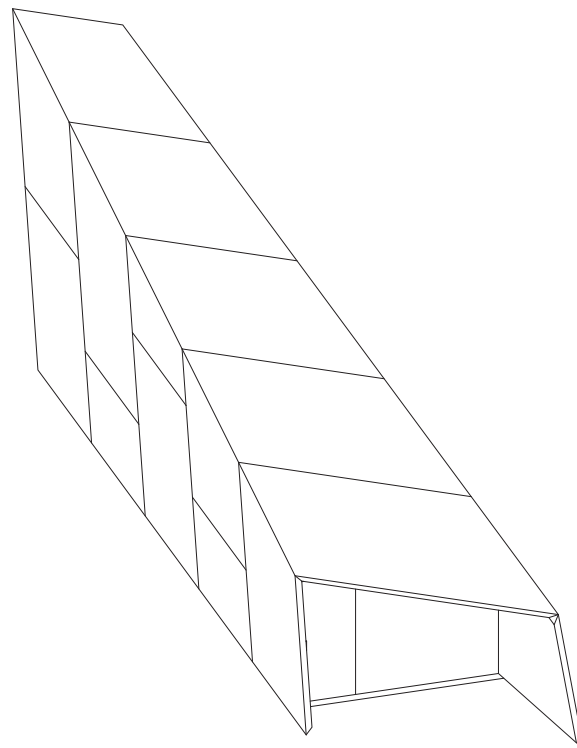
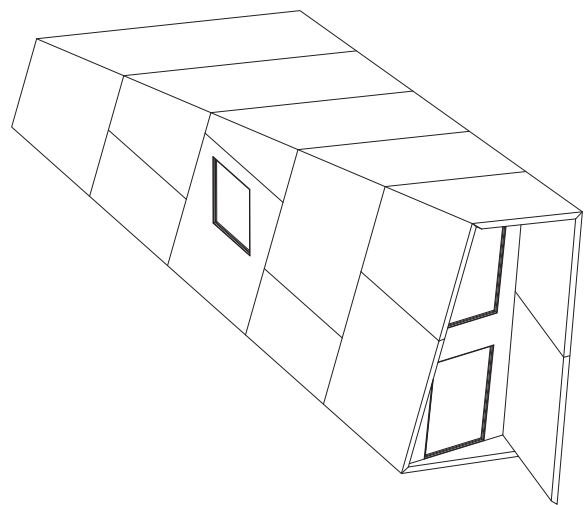


Figure 59:
Plans of rooftop Single
Unit Apartman
Scale: 1:100

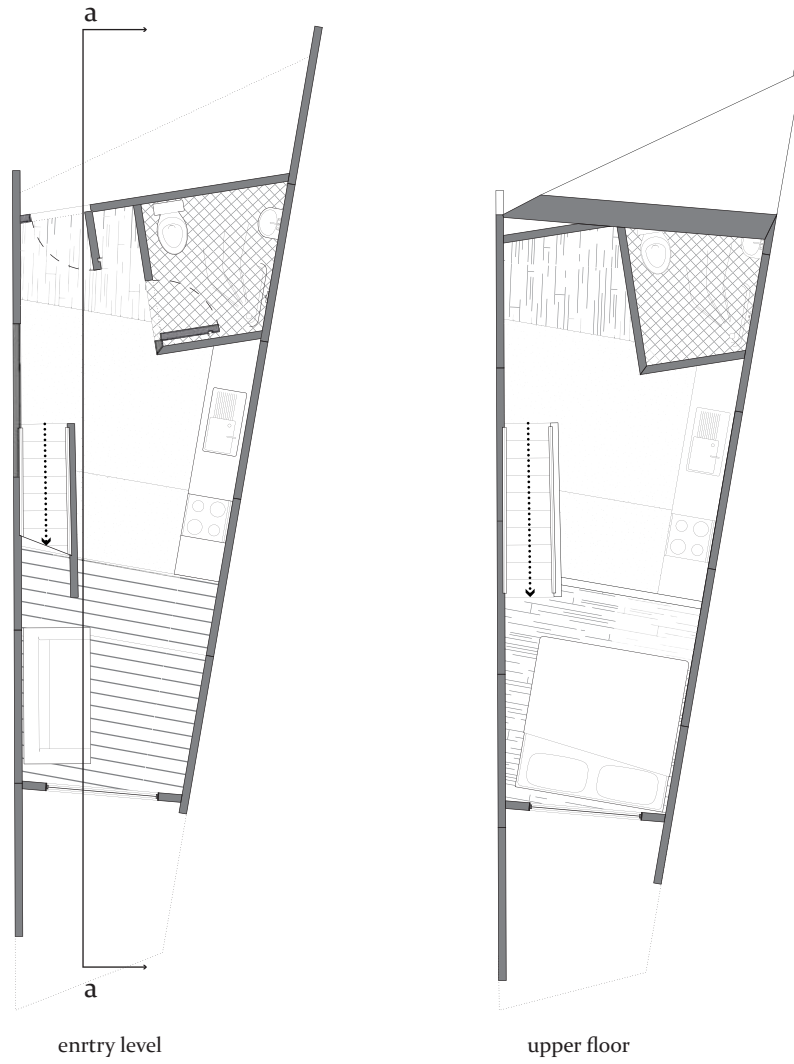
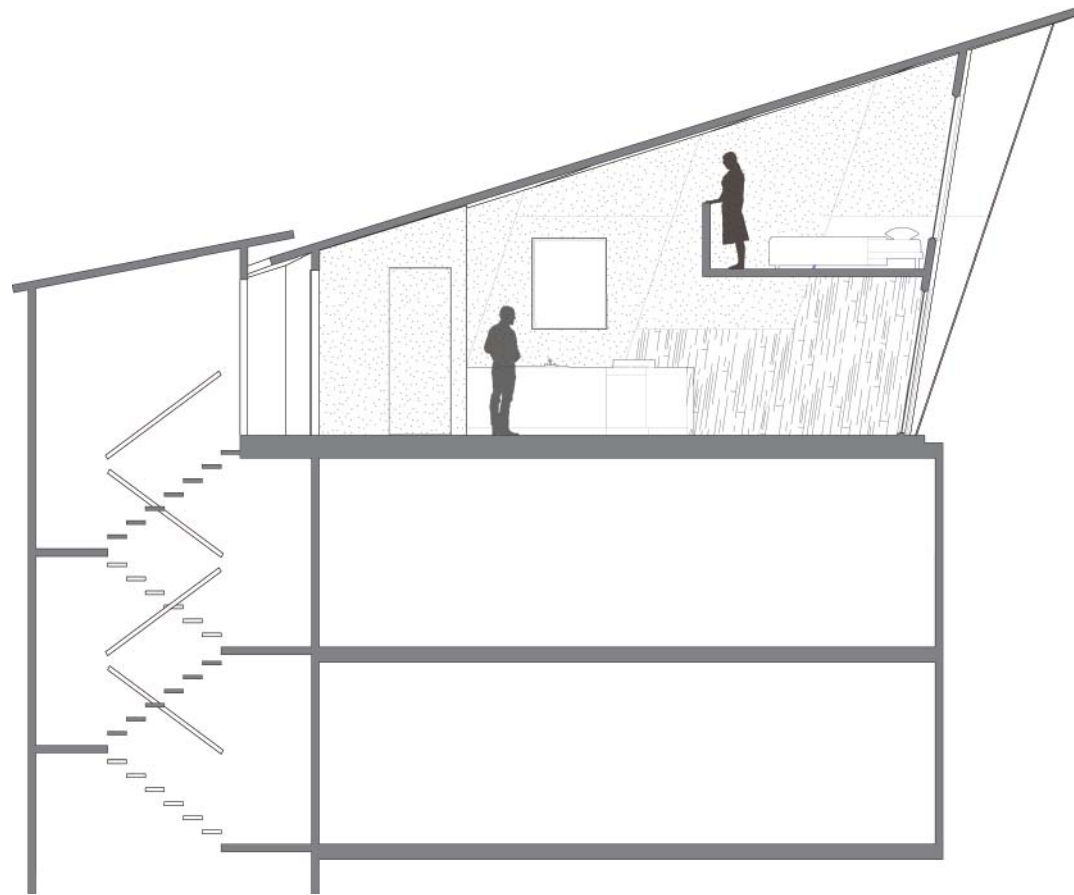


Figure 6o:
Section aa of rooftop
Single Unit Apartman
Scale: 1:100



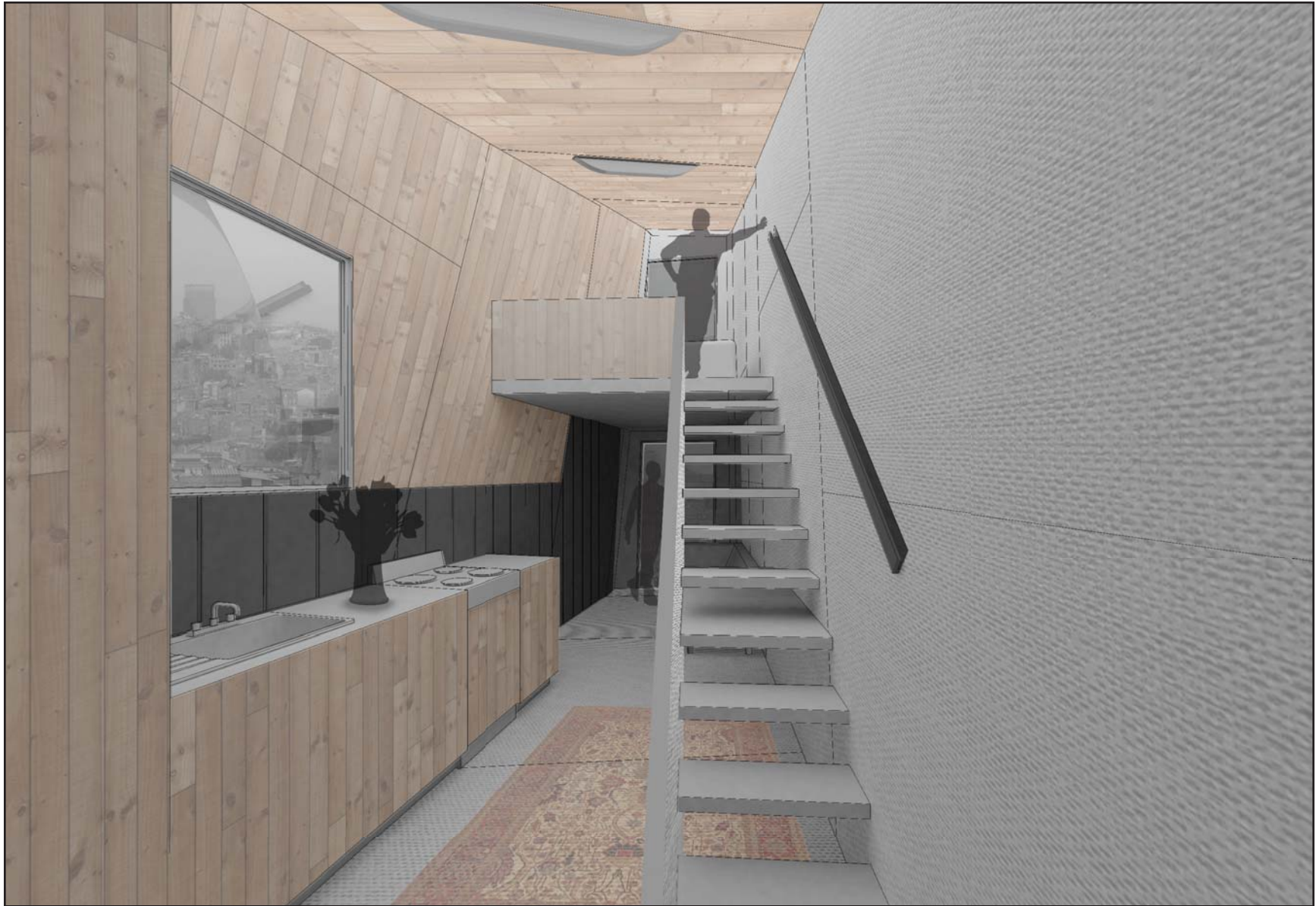


Figure 61: Interior of rooftop Single Unit Apartment
90



Figure 62: Urban landscape of İstanbul, showing a rooftop unit and other apartmanlar.



Appendices and Bibliography

Appendix I: Parametric model

The rapid movement from basic design inputs like site dimensions, unit type, unit capacity, sun angle, etc. to fabrication files is a key step to making viable this proposed construction process. Should an apartment require a designer to work on each project's details, the benefits of mechanized production are lost in hours of computation work.

While this project has not proposed an actual design program, parametric models of the panelization system helped in the creation of the prototype designs shown in this thesis.

At right are shown various parametric variations of the exterior (shell) geometry of the apartment units. Using the parametric tool developed, one can control for sun shading or cantilevers of a single unit and also unit dimensions and angles. These two parameters were seen as the most crucial in overall design work. Interior partitions and fenestration were added after the shell is made via manual methods.

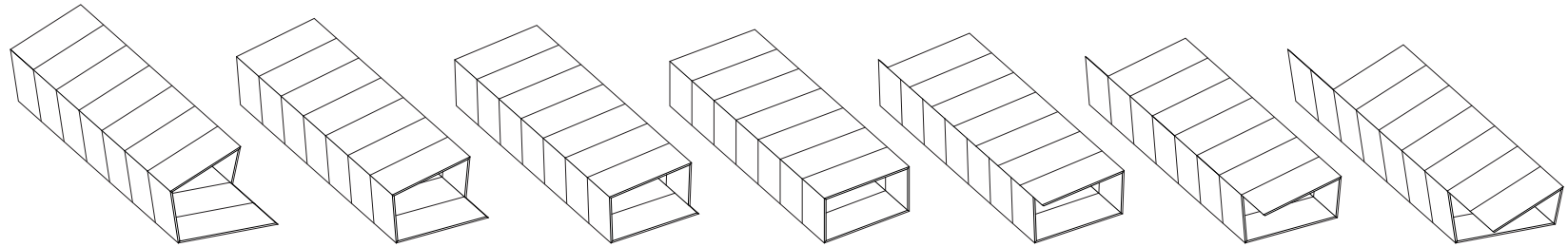


Figure 63: Variation of simple shell volume shading.

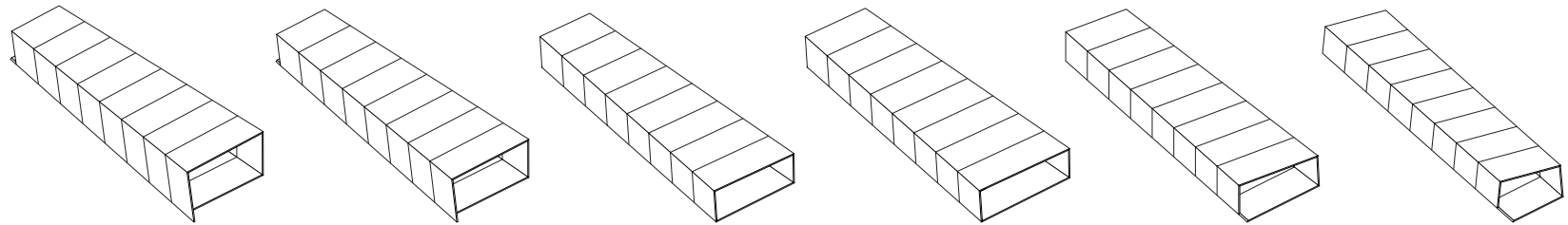


Figure 64: Variation of shell geometry.

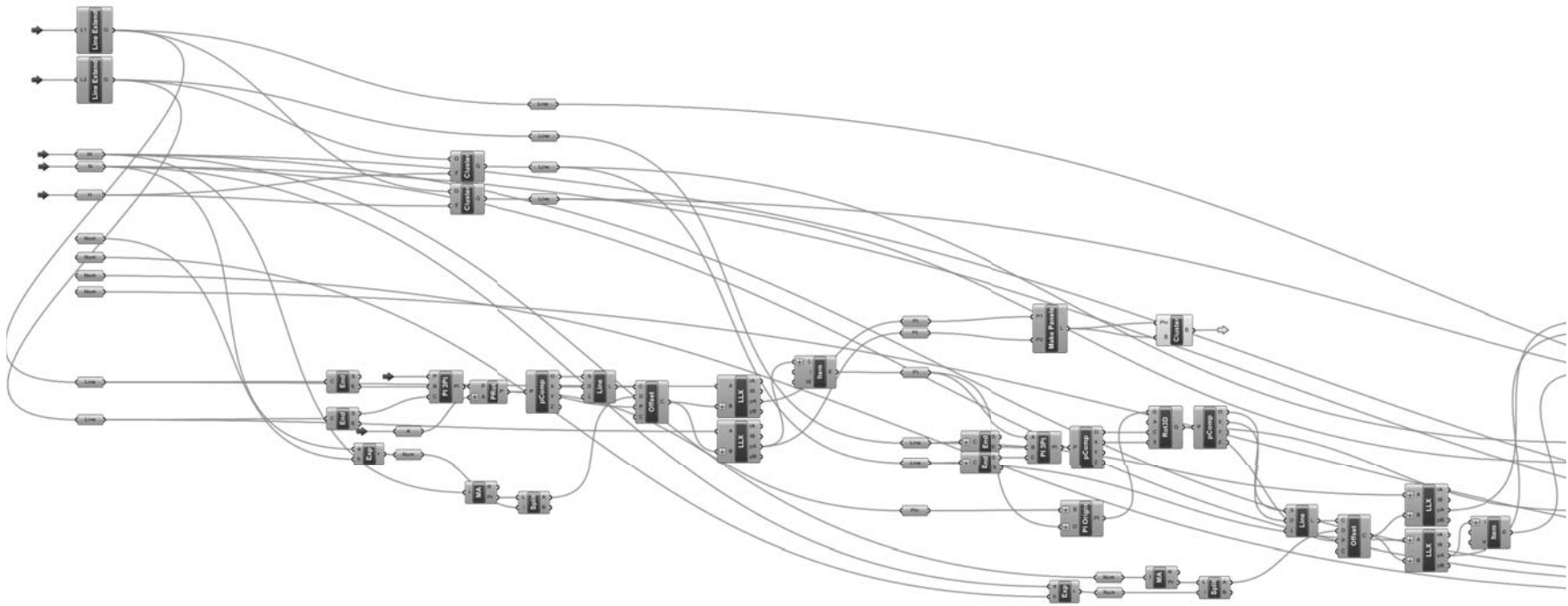
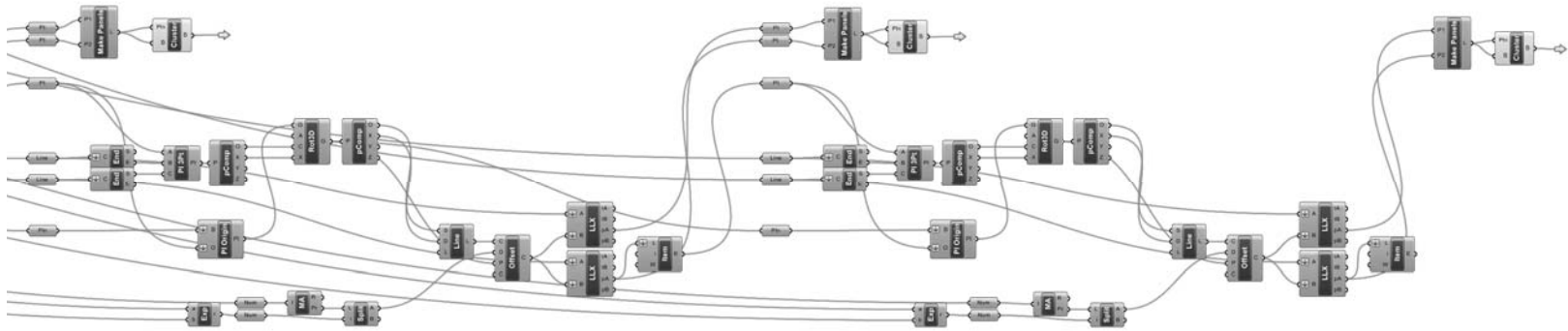
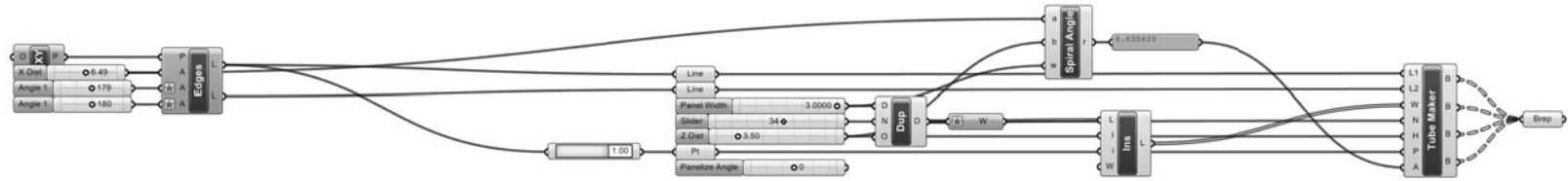


Figure 65: Parametric model definition for shell creation.



Appendix II: Joint Details

The joint design from this project is a variation on work conducted in the spring of 2010 on a lightweight housing prototype for reconstruction after the Haiti earthquake in January, 2010.

There are three pultrusions available for the purpose of not only forming joints, but also other construction details as well. The high cost of creating new dies for new pultrusions limits the number of available sections. Therefore, creating sections that allow for variable use depending on how they are milled is crucial. Furthermore, each section must remain structural sound in that loads must be transferred from the glass fiber skin on one side, through the pultrusion, to the other side.

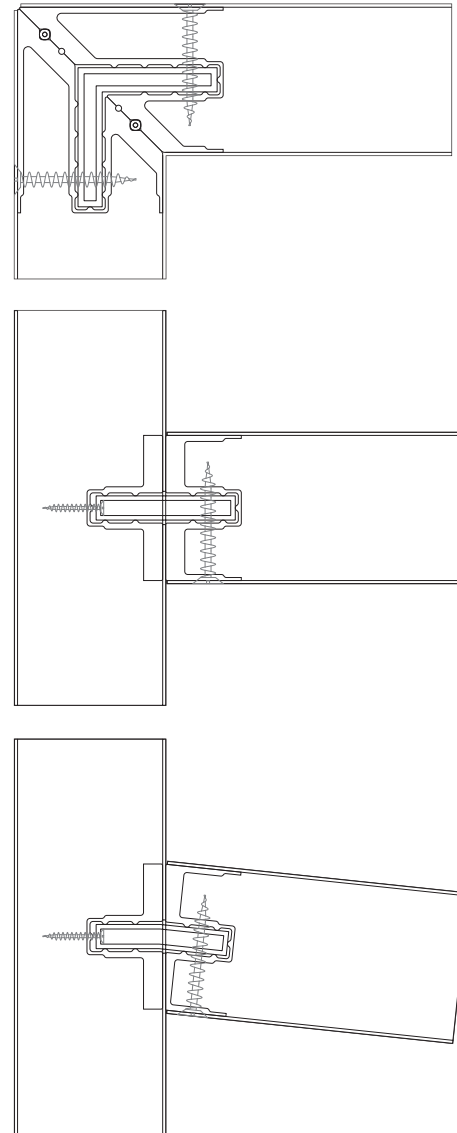
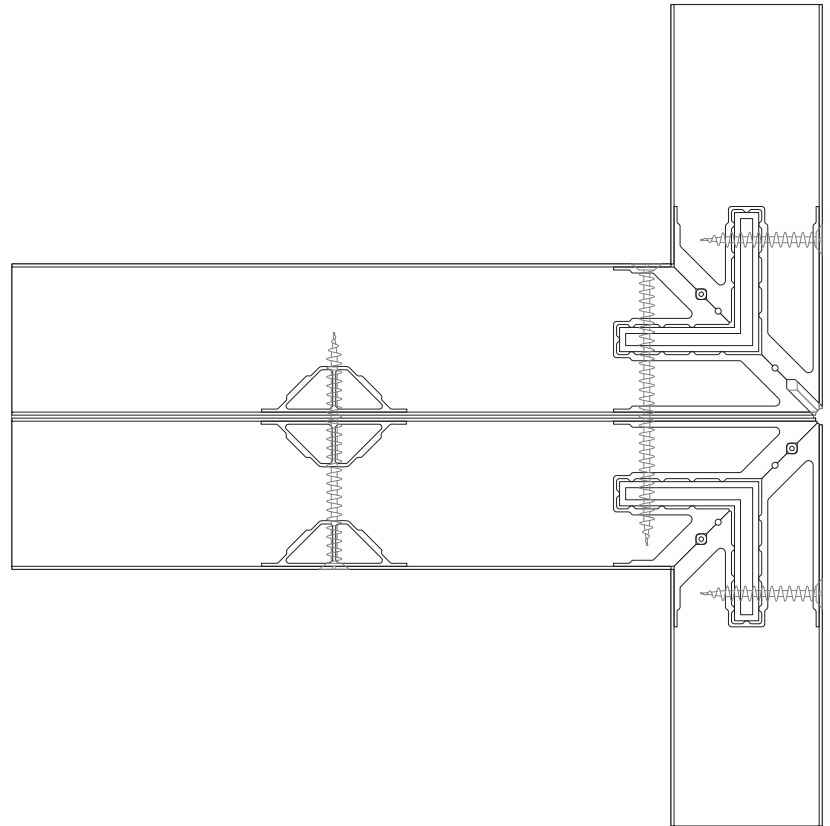
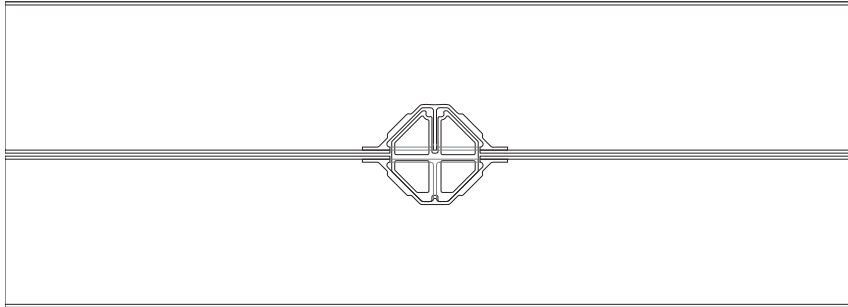
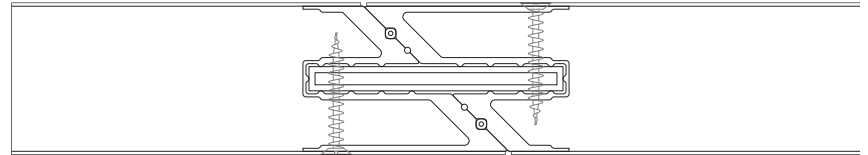
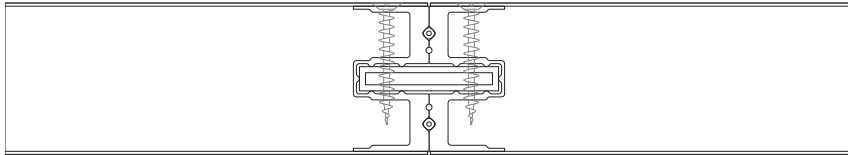


Figure 66:
Various joint details
Scale: 1:5



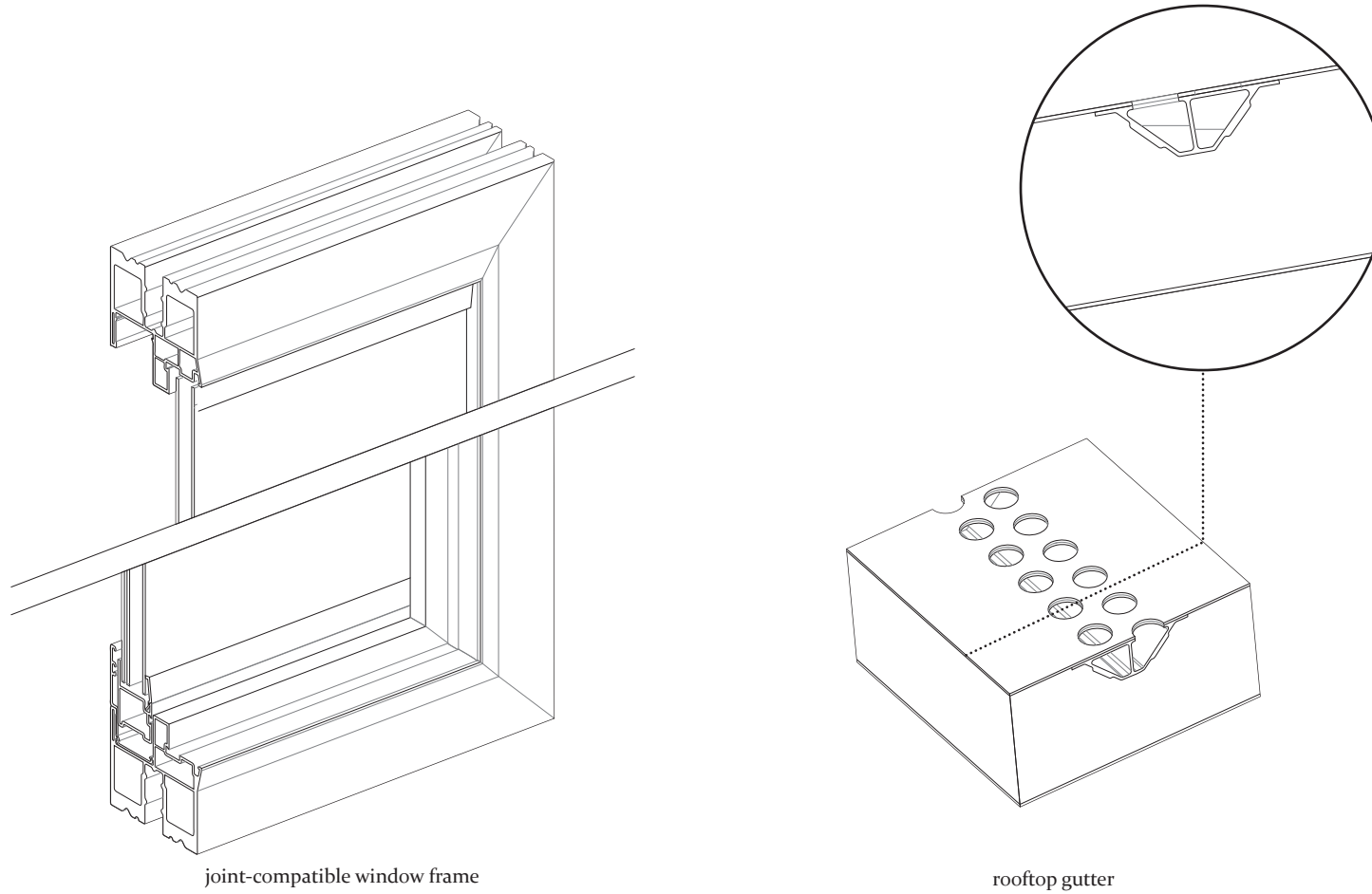
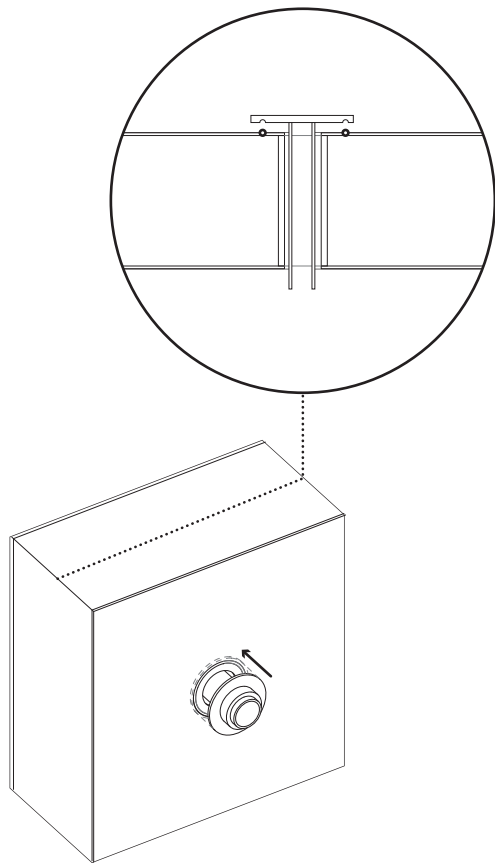
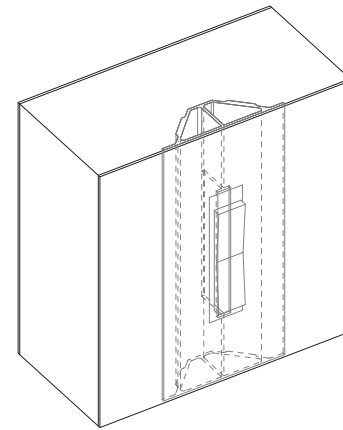


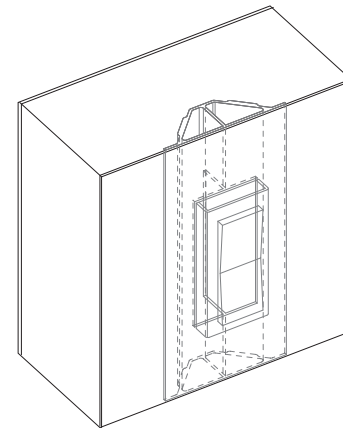
Figure 67:
Various building system components..



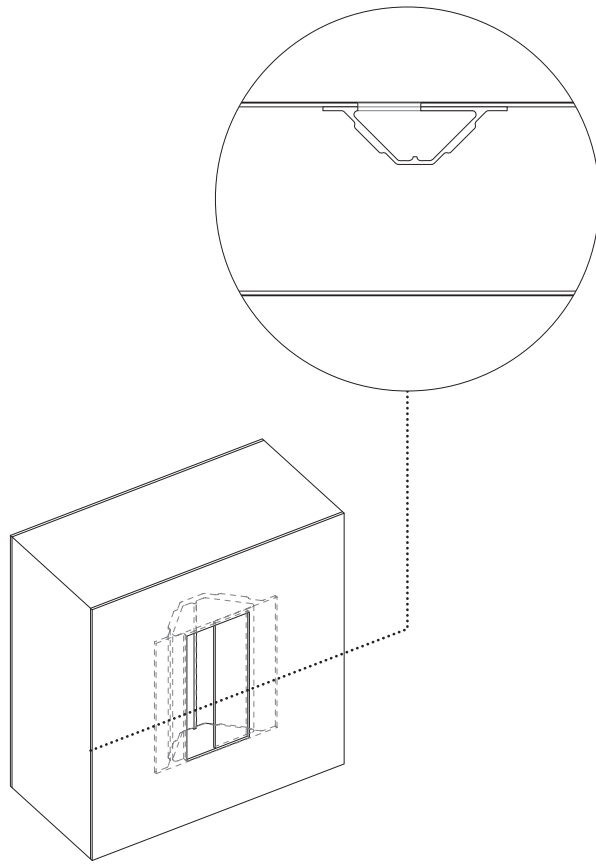
pipe penetration



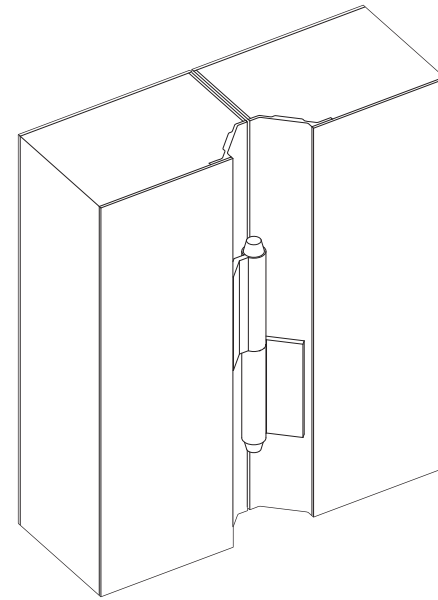
flush wall switch



raised wall switch

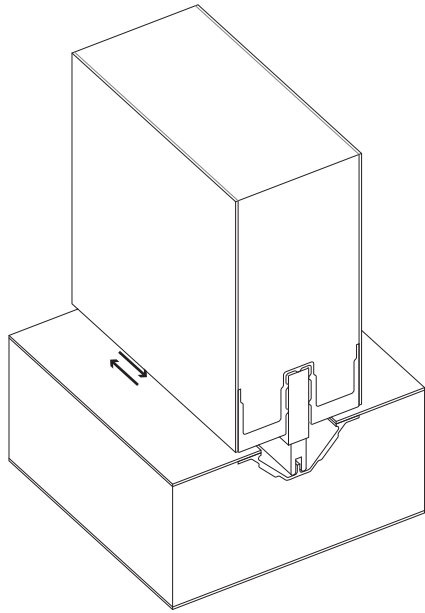


door handle

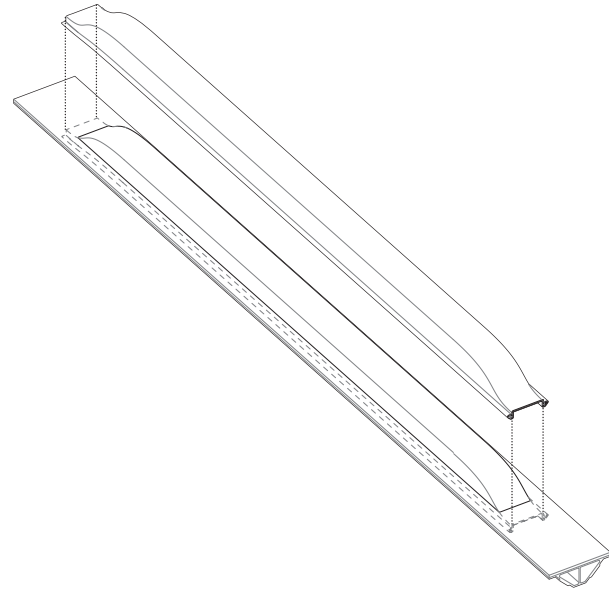


door hinge

Figure 67:
Various building system components (cont'd).



sliding door track



light tube

Appendix III: Model Investigations

The larger configuration of panels to form a structure was investigated through models both physical (for general form-exploration) and digital (for checking specific limitations of panel connections).

While the possibilities of volume-making are great, the more closed, unit-based systems were preferred because they could be made easily weathertight and structural, without depending too highly on any single connection.

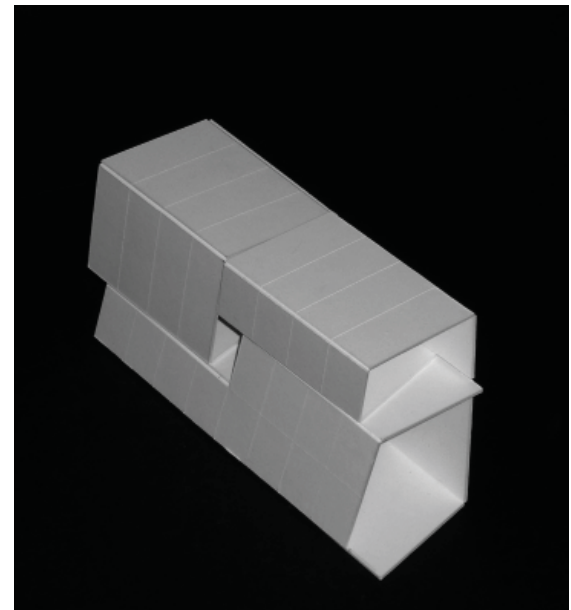
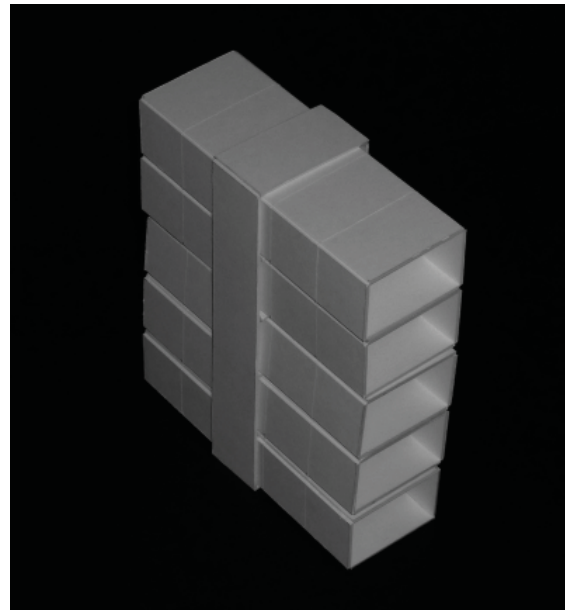
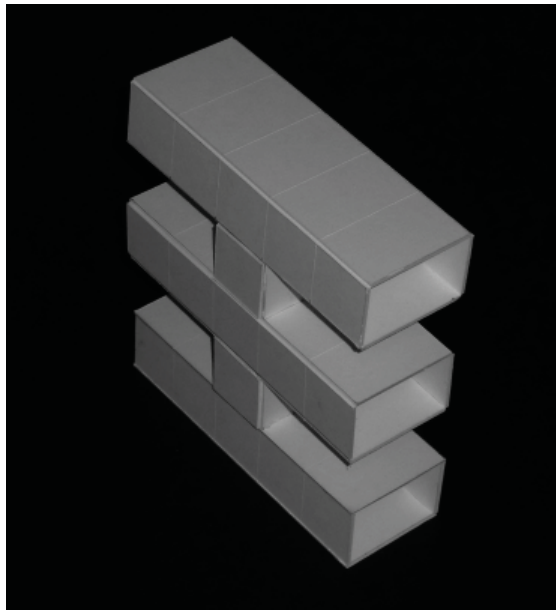
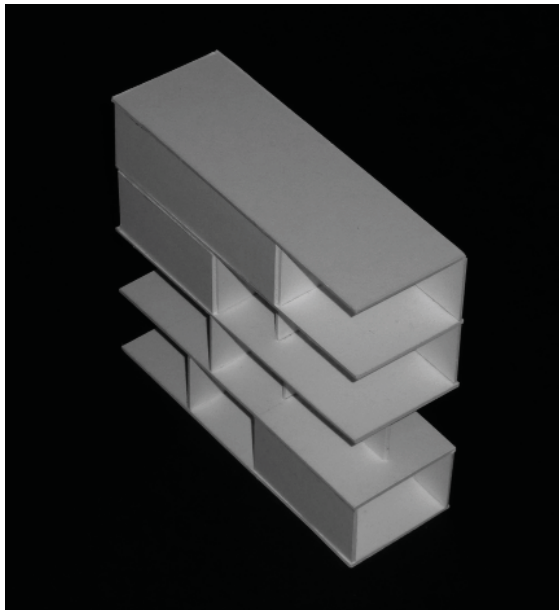
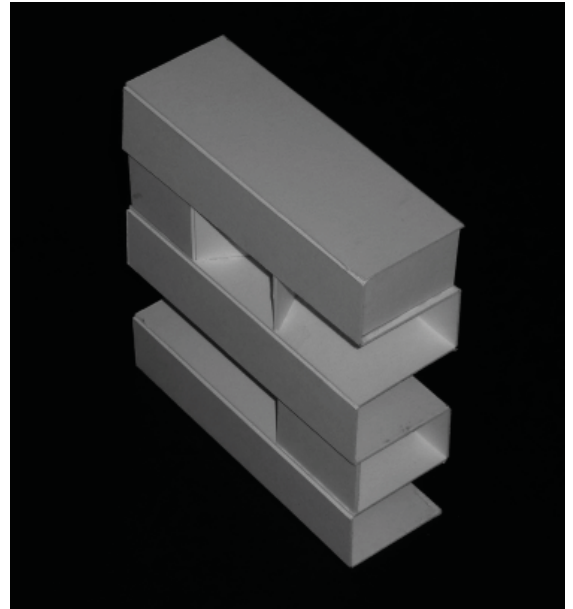
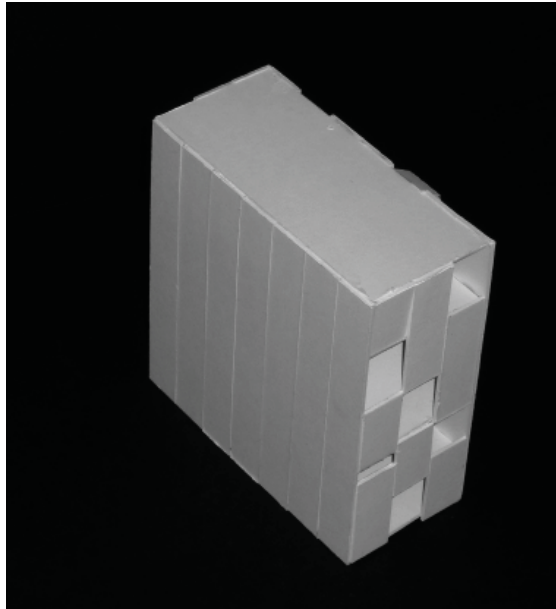
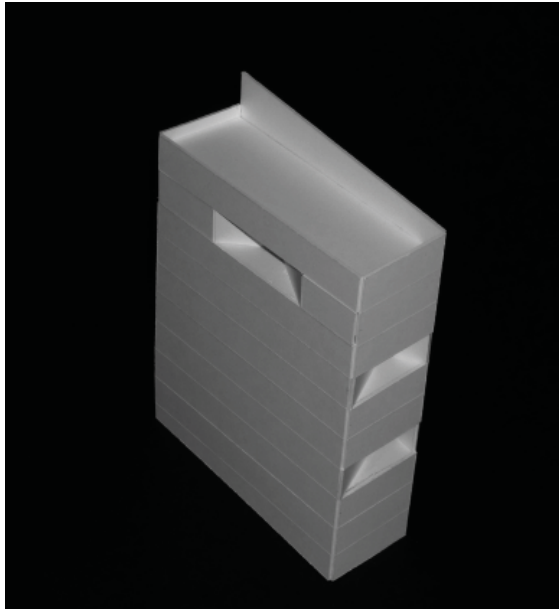


Figure 68:
Models showing possible panel
configurations for buildings.



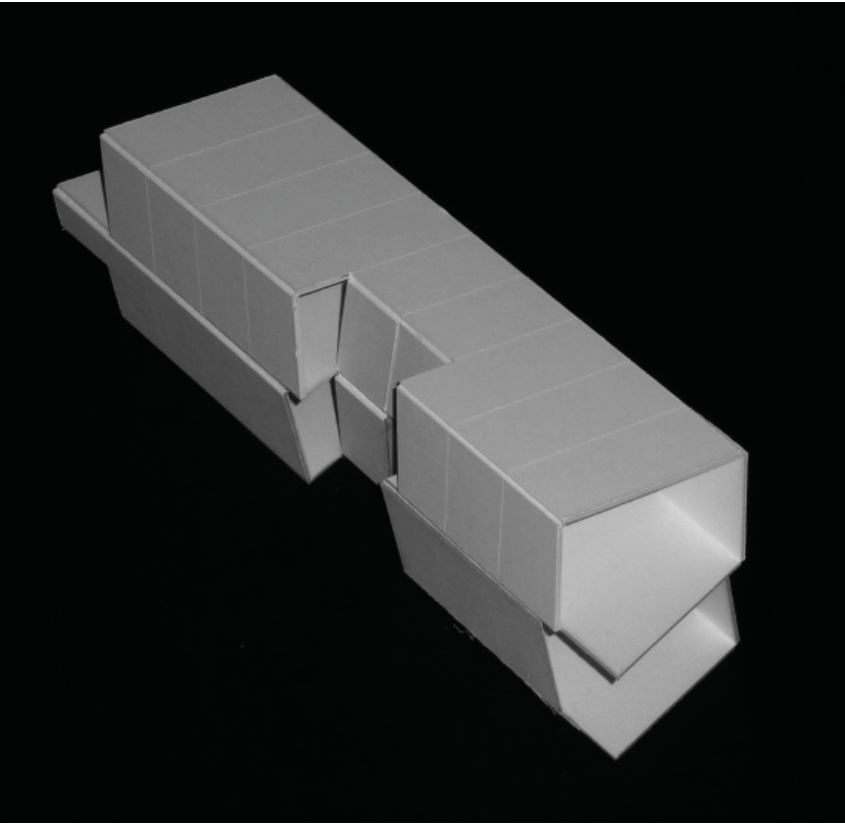
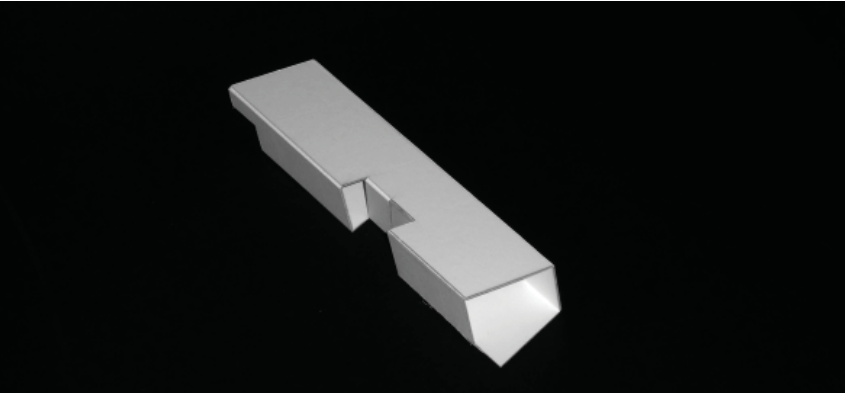


Figure 69:
Models showing units and
stacked unit configurations.

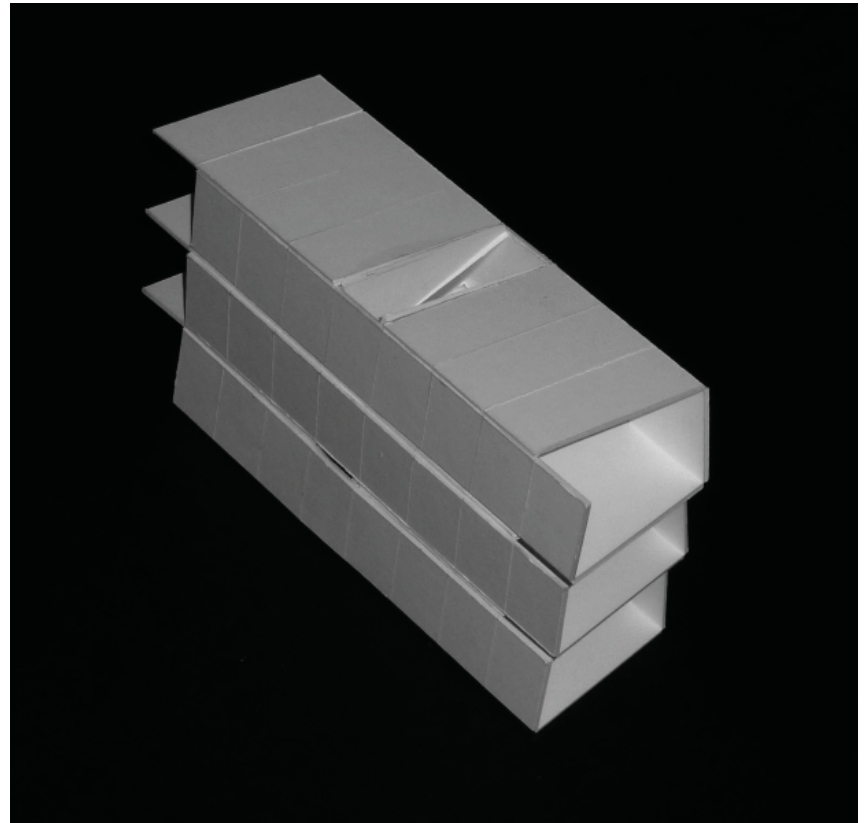
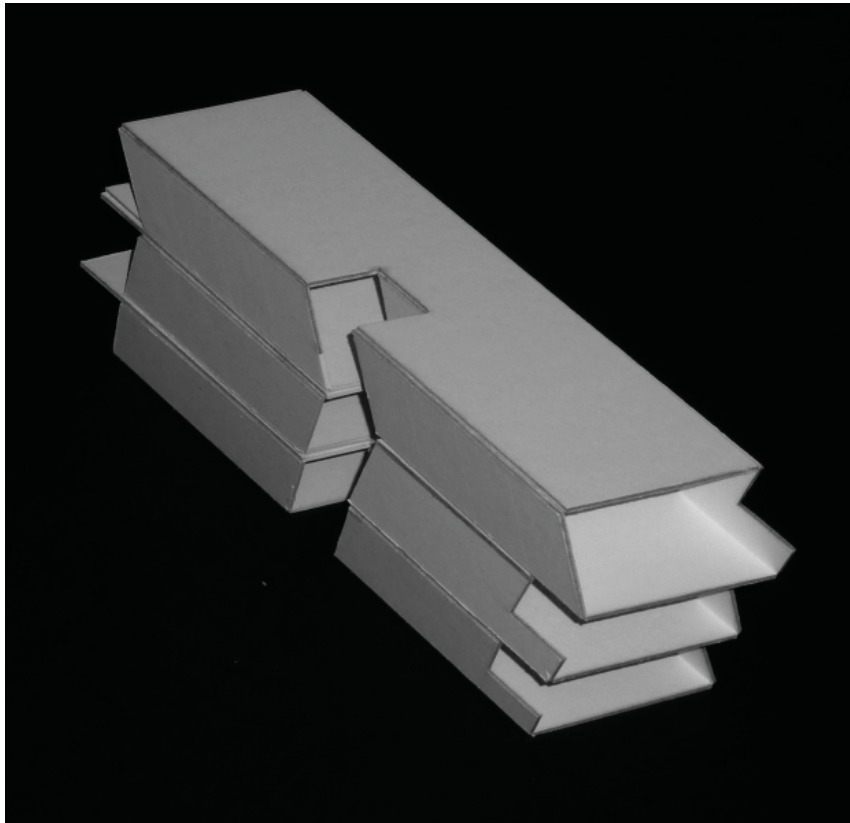
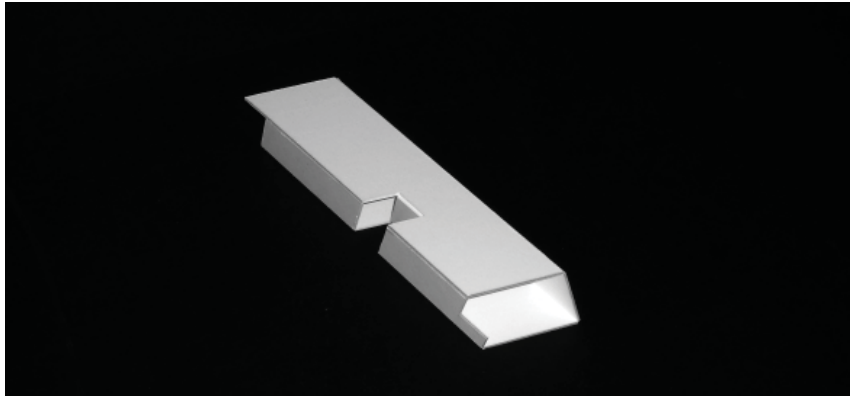
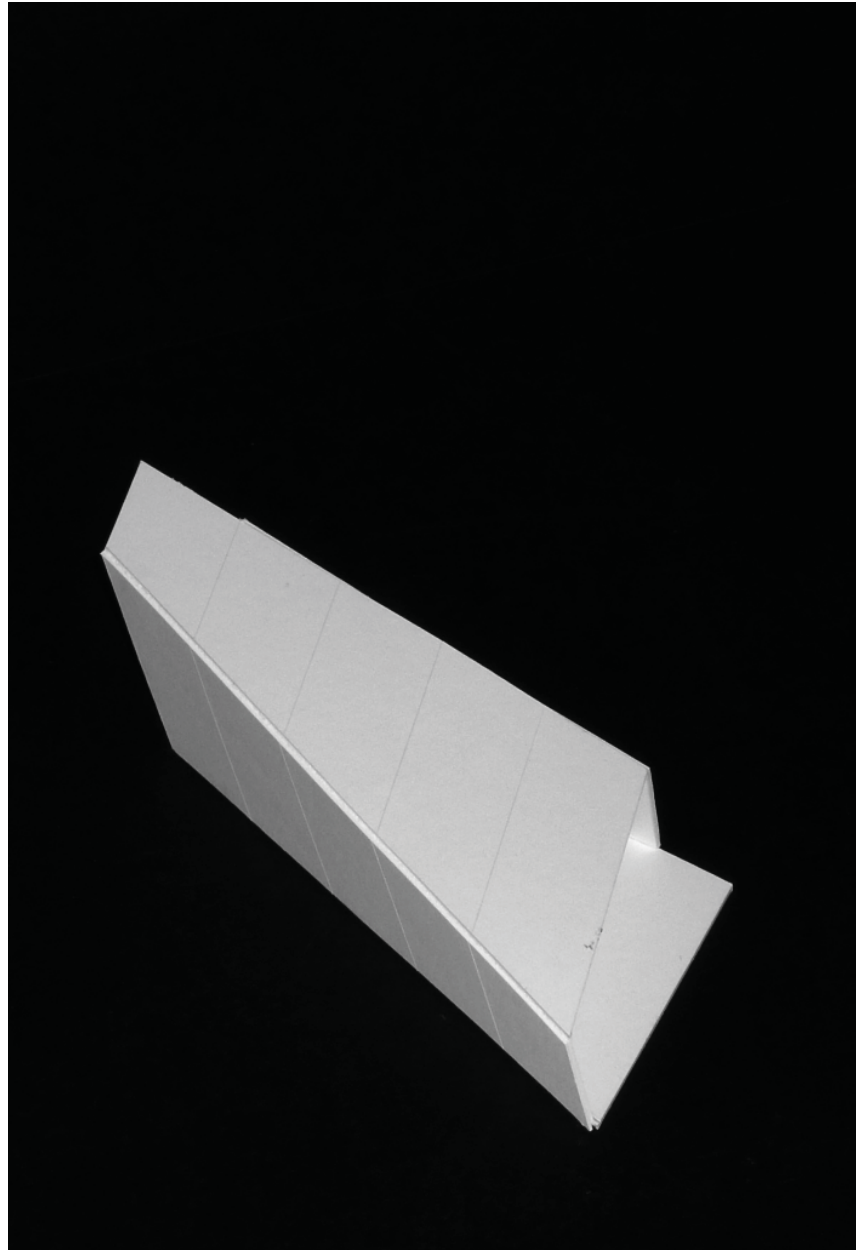
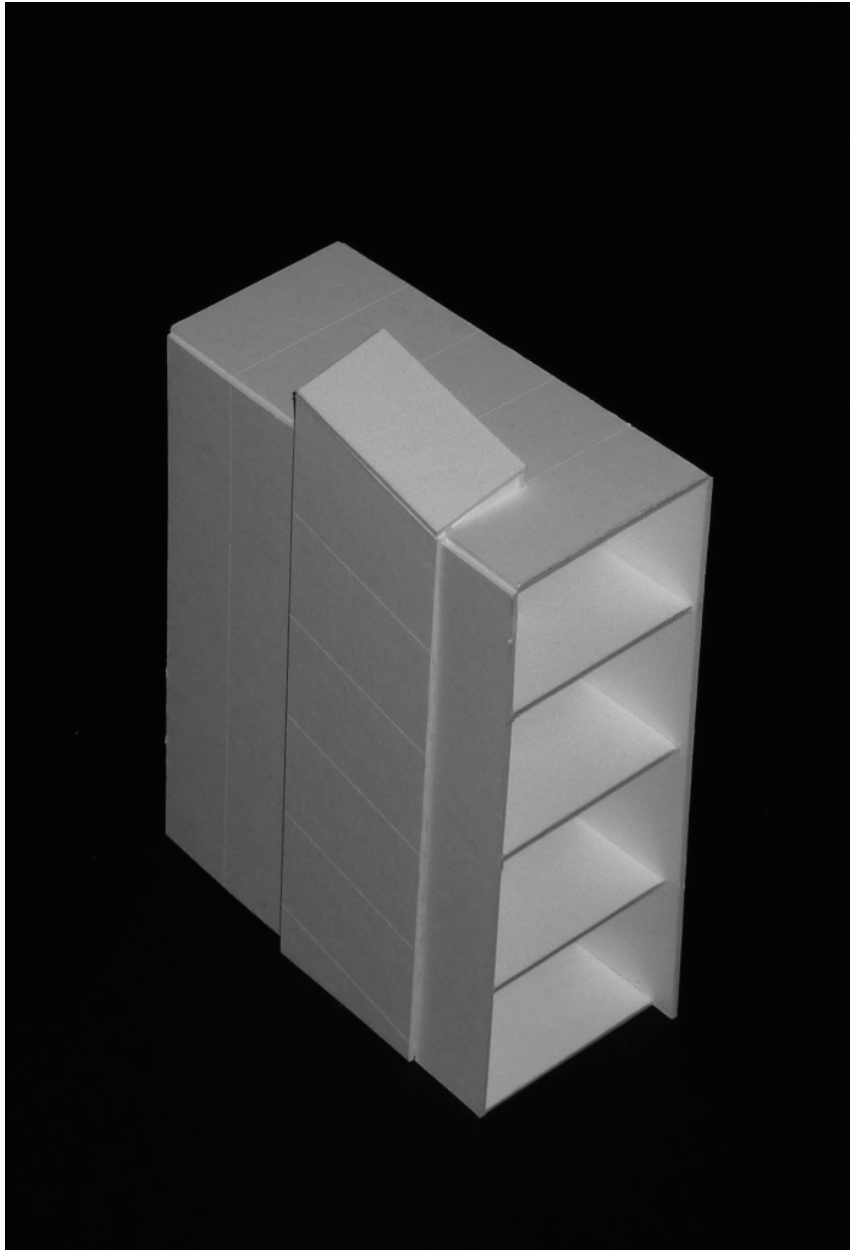




Figure 70:
Models of the three final proposals.



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Colophon

All drawings and photographs by the author with assistance from Curtis Roth, Christopher Guignon and Christopher Miller.

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