

Emergence and Complexity: Designing a Fire Station for Informal Settlements

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In South Africa's Johannesburg, miles upon miles of land are covered by informal settlements, unincorporated areas of the city where hundreds of thousands of inhabitants live in unplanned settlements. These settlements are often illegal and do not comply with local planning and building regulations. For many decades, countries across the Southern Hemisphere have seen an explosion of such unplanned and unincorporated areas. The causes for the proliferation of these settlements, however, are not simple, nor can they be solely placed upon the shoulders of those who choose to live in them. Severe income inequality, wage stagnation, systemic discrimination, and government corruption have all contributed to the growth of informal settlements over the decades, and Johannesburg is no different. Decades of violent apartheid in South Africa systematically excluded an entire group of people, namely black South Africans, from being part of the society. In so doing, millions were robbed of their futures, leading to incredible income inequality and severe mistrust of government institutions.¹

Though apartheid has been over for almost thirty years, the effects of systemic discrimination and government corruption have lingered into the present, as hundreds of thousands of people continue to live in informal settlements across South Africa. This huge swathe of land covered by informal settlements brings its own unique issues regarding the health and well-being of the community, especially when it comes to the spread of deadly fires. Makeshift houses made of loose scraps of corrugated metal, wood, and plastic are packed together with no running water, haphazard electric lines at overcapacity, and open containers of gasoline that power many of the inhabitants' stoves. Combine these fire hazards with 1) community mistrust of local fire responders from days' past and 2) the inability for responders to

¹ McKaiser, E. (2020). In South Africa, police violence isn't black and white. *Foreign Policy*.

reach the often jungle-like conglomeration of metal shacks, and you have a dangerous risk of unstoppable fire spread.² In fact, every year fires destroy parts of the informal settlements, killing hundreds and sometimes thousands of people, and displacing thousands more. To address these issues, a new fire station design was requested for the area of Orlando West in Soweto, a township of Johannesburg. The needs of the fire station were two-fold: first, to considerably reduce the ignition and spread rates of fires plaguing the community by not just responding to fires but also by teaching fire safety techniques to reduce the chances of ignition, and second, to cultivate a collaborative relationship between fire responders and informal settlement inhabitants. This was no easy task, however. A fire station that can achieve these goals needed a design which was highly efficient and functional, responsive to needs both within the fire station itself but also the community at large, and above all else, open and welcoming to the community it plans to serve.

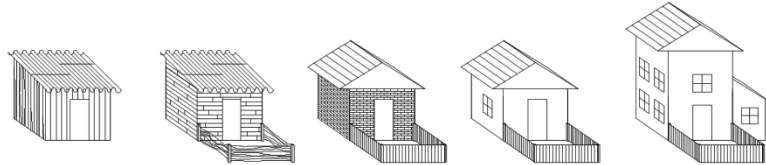
Achieving the goals of functionality, responsiveness, and receptivity meant first understanding the values of the inhabitants, and this is where we begin with our search for a design concept. Inhabitants of informal settlements are not usually stagnant individuals but are rather prospective, adaptive, and forward-looking.³ They rarely stay attached to the past. This rejection of unhelpful nostalgia and the latching onto a positive vision for the future means that inhabitants are always striving for forward progress and positive transformation of their environment. Many of them do not see themselves as staying within the informal settlements for the rest of their lives, but rather, as soon as they can, leaving for better and more permanent prospects.⁴ This is where the concept of evolution can be found within informal settlements.

² Walls, R., et al. (2020). Fire safety engineering guideline for informal settlements. *FireSUN Publications*.

³ Pojani, D. (2019). The self-built city--theorizing urban design of informal settlements. *International Journal of Architectural Research*.

⁴ Pojani, D. (2019).

Because inhabitants are making individual decisions according to their own survival needs and comfort, there is a constant experimentation with the environment, and with this comes a constant evolution on the individual household level.

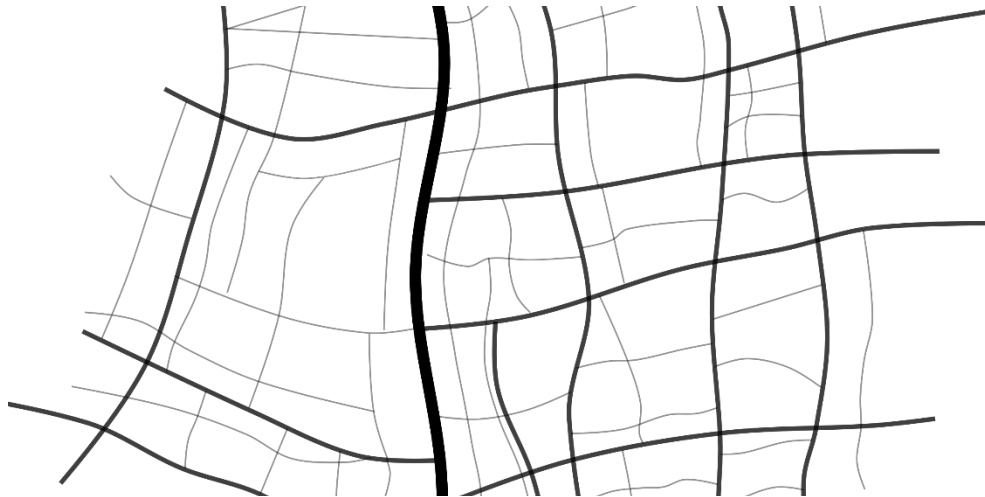


Individual evolution on the household level.

But this individual level evolution is also mediated by the evolution of the households around them. Thus, individuals are not simply singular entities operating within a vacuum but are rather part of an interconnected network of individuals all working towards surviving and improving. Decisions on the individual level therefore impact decisions on a macro scale, and thus, the entire community. This is the level of group evolution, where a community evolves from the growth of an interconnected network. Furthermore, the growth and composition of settlements is, for better or worse, not controlled through top-down planning. Rather, the growth and composition is directly controlled by self-interested individuals making their own decisions.⁵ Thus, an order arises from the bottom-up. In the field of biology, this is known as *self-organization* (or spontaneous order) where singular elements interact through the mediation of genes and the environment to form a complex and ordered system, an emergence of order out of seeming chaos. Life on Earth, language, and free market economies can all be thought of as examples of systems that have evolved through self-organization. Through this spontaneous order emerges unique properties that cannot be found within the individual elements, creating an

⁵ Kamalipour, H. (2016). Forms of informality and adaptations in informal settlements. *International Journal of Architectural Research*.

emergent complexity that arises from the *interaction* of the individual parts rather than from the individual parts themselves.



Group level evolution.

This is how informal settlements evolve and are maintained: individuals making self-interested decisions for the betterment of their lives mediated by the interaction with other self-interested individuals, creating a dynamic, adaptive, and ordered system among seeming chaos.⁶ The emergence and complexity of informal settlements and the values of forward progress and transformation embodied by the inhabitants form the foundation of the fire station's design concept.⁷ Thus, using the values of forward progress and transformation by taking singular elements and combining them into a functional and adaptive whole, we were able to implement a fire station design that can respond to the needs of the inhabitants and build a healthy and collaborative relationship with the community. This process of implementation, however, is where the abstract concept and physical architecture meet.

⁶ Kamalipour, H. (2016).

⁷ Pojani, D. (2019).

Generating an abstract concept from the values of the inhabitants is one thing; applying the principles of the concept to a physical design is another. First, the location of the site brought many challenges. Its high degree of slope and location near railroad tracks to the west, along with a need for a secure facility, created design problems, but the proximity to informal settlements mattered the most. Second, the layout of the fire station had to follow the design concept: the emergent complexity of singular elements interacting to form an ordered whole. To enable flexibility with the site constraints while connecting the layout of the fire station with our design concept, we utilized the existing axes from the nearby informal settlements and extended them onto our site. Doing so provided lines that acted as the boundaries for our building geometry. These boundaries then allowed us to define the layout for six distinct and interconnected forms that respond to different site conditions and functionalities. Each one, while unique in rectilinear form and placement, works together for the entire fire station. Within this geometry forms an extensive circulation system that acts as the glue, bonding the singular forms together into an ordered system. After generating the forms, the site lines that ended within the geometry then extended back outward across the site. This created paths that reach out towards



Context plan shows how we used lines from the context to generate the six forms.

the community on both the north and south sides of the site, emphasizing the design goal of receptivity.

While the massing and site conditions were integrated with the design concept by using singular yet interconnected forms, along with paths that extended out from those forms, a much more critical need arose when it came to the façade. If the building was to be open and welcoming to the community, there needed to be an open and welcoming façade that could cultivate a collaborative relationship between the fire responders and the inhabitants.

Accomplishing this successfully was not an easy task, however. Our first exploration of façade design emphasized a heavy use of brick to communicate solidity with the earth and community, while a glazing system contrasted this solid brick with open views into the spaces. And yet this open glazing system was blocked by a heavy array of aluminum louvers. These louvers were highly functional in that they shaded the inside of the spaces, but at the same time, they were rather unappealing because they made the façade look dark and uninviting. Combine the array of louvers with a heavy amount of brick, and we found ourselves with a dark bunker rather than an open and welcoming fire station. Furthermore, the façade design did not tie back to the concept of emergence and complexity. The brick and louvers were not arranged in a dynamic, energetic, and adaptive way, and they failed to follow the same design principles utilized during the generation of the overall forms. This was the major critique from the professionals during

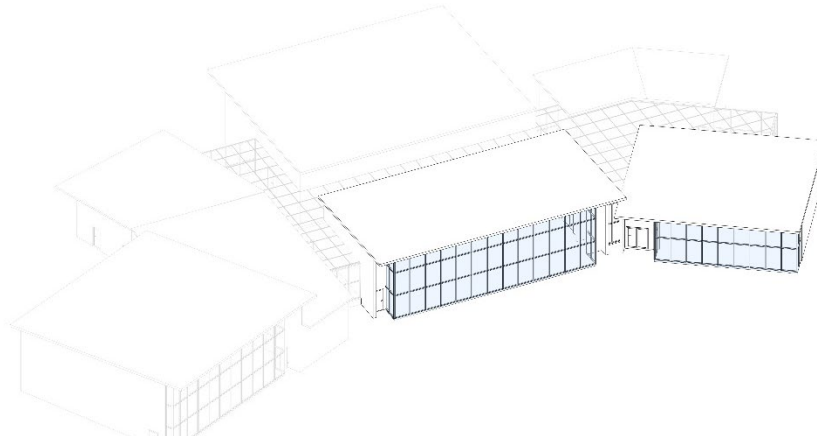
Schematic Design, and it provided us with an opportunity to return to our concept when we redesigned the façade for Design Development.



Schematic Design facade. The design is dark, solid, and uninviting.

Design Development began with a simplification of the unique building forms so that they were more cohesive while remaining separate and distinct, yet beyond this, much of the DD phase was spent exploring the new façade design, from which the concept would be articulated. The goals of the new façade design were threefold: 1) open the north-facing solid walls to allow more daylight into the space, 2) create a more welcoming environment for the community, and 3) implement a design that emphasizes the concept of emergence and complexity: combining many singular parts into an adaptive and ordered system. Through the generation of design goals, it was clear that both aesthetic and functional concerns had to be balanced with the concept. The façade needed to be both artistically energetic and dynamic yet also shade enough of the sun to regulate the amount of daylight, heat, and glare coming into the spaces. The first and second design goals were achieved by transforming the solid brick walls into 95% north facing glazing, allowing a tremendous amount of daylight into the space and opening up the front to be more

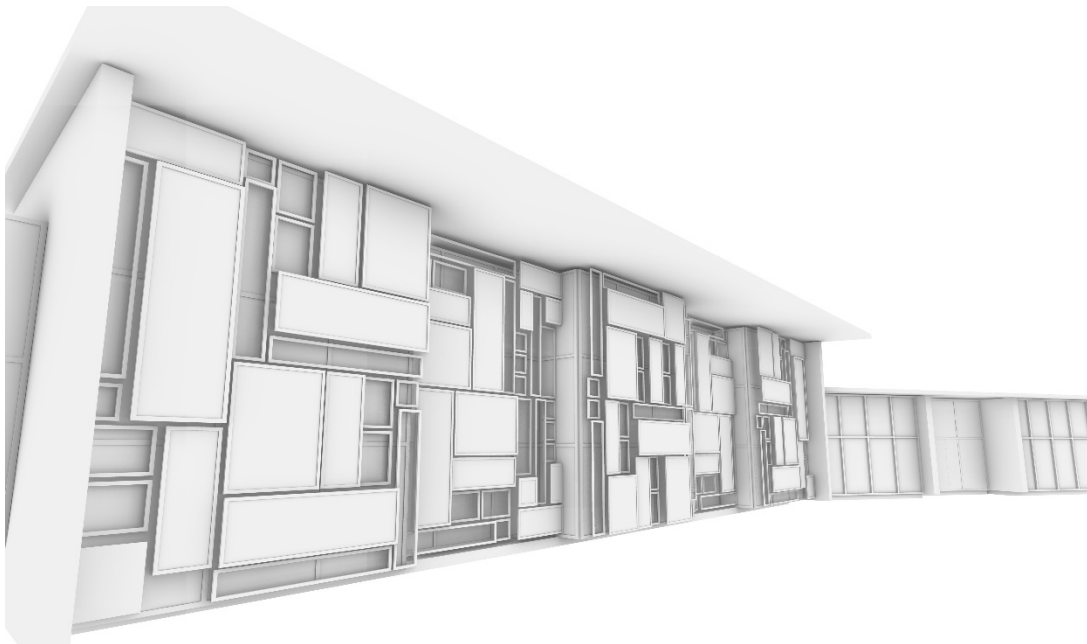
welcoming. With this increase in glazing came the issue of shade: how can the large amount of glazing be shaded in a way that fits within the design goals and concept?



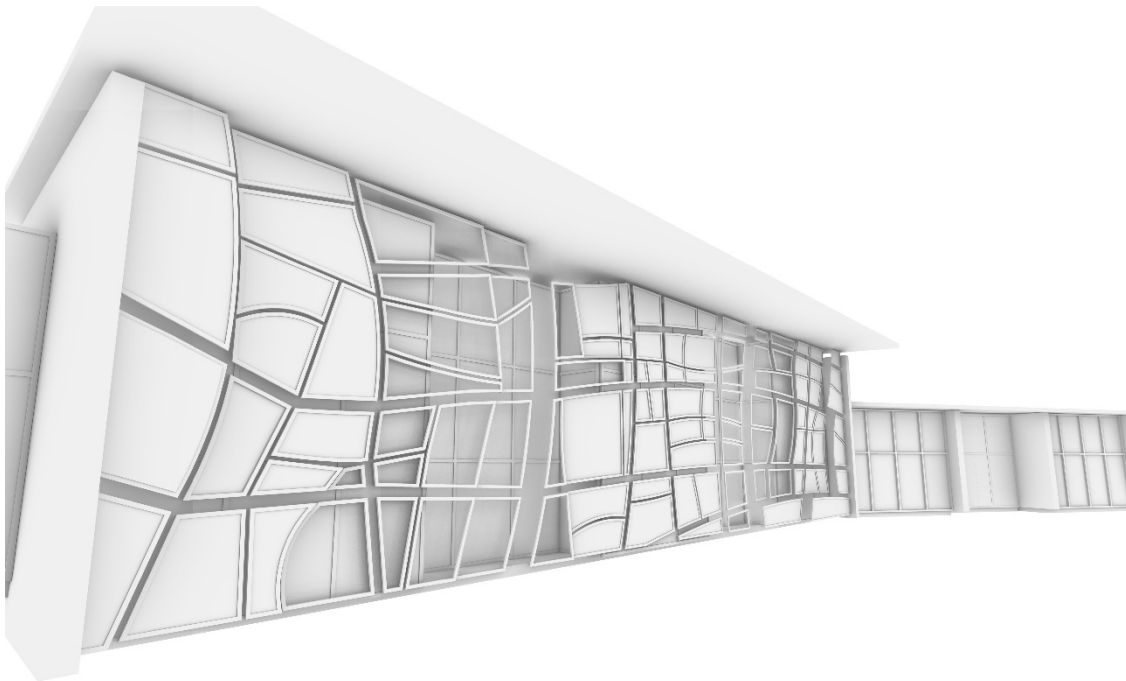
North facing glazing (in blue) required shade.

To achieve the goals of providing shade while also maintaining the openness of the facade, I explored two unique shading devices that utilized the properties of individual and group level evolution to bring about an emergent complexity. Each of the two shading device designs utilized a series of metal panels and metal mesh that would attach to the glazing. The metal mesh would provide transparency and the metal panels would provide a solid covering. Both designs were generated using boundary lines, like the generation of the initial six forms, to create a complex composition where each panel was unique. The boundary lines formed the gaps between the panels, and the gaps were three different widths to show the different layers of complexity within informal settlements. The first gap was largest, representing the largest axis; the third gap was the smallest, representing the axes between individual households; and the second gap was in between, mimicking the roads connecting different groups of households. The difference between the two designs was found in the shape and movement of the panels. The first

used a series of rectilinear panels arranged in different orthogonal rotations of 0 and 90 degrees, creating a composition that mimicked the art of De Stijl.



First metal mesh/panel design mimicking DeStijl.



Second metal mesh/panel design using organic curvilinear systems.

The second used curvilinear lines moving in horizontal directions across the facades, mimicking the composition and layout of informal settlements from a satellite view. The dynamic form of the second curvilinear shading device meant that this would provide a much more energetic façade compared to the first rectilinear design, and it provided a composition that was much more relatable to the South Africa's art aesthetic.



Final rendering of the curvilinear shading device system, integrating singular unique elements into a cohesive whole.

In generating the layers of complexity by dividing the panels three times, I was able to emphasize the idea of emergence: that an ordered and adaptive system can emerge through the combination of many singular elements, just like the evolution of informal settlements and the values the inhabitants espouse. The singular nature of the panels means that each can be specified to have a solid panel or a metal mesh system to provide flexibility for the use of a specific space. The transparency of the metal mesh, along with the gaps between the individual panels, also solves the problem of openness by keeping the façade light and welcoming and still

allowing a degree of diffuse sunlight into the spaces. The blue tint of the glazing contrasts with the white and light gray panel systems sitting in front, providing differentiation between the shading device and the curtain wall, and the brick walls on the west and east sides from Schematic Design were kept to provide a strong sense of solidity between the glazing system.



Interior render of the Demonstration Space with the metal mesh system applied to the façade and ceiling.

Overall, the shading device combined with the expansive curtain wall glazing solved the problems generated from SD while also re-emphasizing the design concept. Thus, both the façade design and the massing were ultimately generated by the same process of using lines to generate single yet interconnected forms. Through this process, a cohesive system of singular elements combined to create an adaptive and ordered system on both the macro and micro scale of the building project. Furthermore, the major design goals from Schematic Design were addressed: the design was highly efficient and functional using singular and interconnected forms, responsive to needs both within the fire station itself but also the community at large by opening outwards, and finally, welcoming to the community it plans to serve by utilizing the inhabitants' values of prospective adaptation and evolution.

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