Author:
Nicola Smuts
Supervisor:
Christo van der Hoven

INFORMAL INTELLECT:

Germiston Station

a journey in
generative
form-finding towards
regenerative
public space

Abstract

This is a journey of placing people in the foreground of rail infrastructure, mediating between efficiency of urban mobility, and the opportunity to foster equity through the many scales that come together in station typologies. From building to streetscape, from city to nation, or even continent, rail is reimagined as the connective veins that foster and feed regenerative urban morphologies.

Germiston Station is the platform to Africa and serves as the core of the Metrorail network. The client, PRASA, has made markable progress in restoring the commuter network ever since its collapse in 2020 – markedly, we are on the brink of a rail renaissance – branded with the deployment of new blue electric trains with increased speed and efficiency. Yet the planned renaissance, marketed with *"The People's Train"*, has failed the people. PRASA's recent ban on trading, gospel and gambling – all acts of communion during commute – has been met with resistance. For decades, such acts have forged hope amid the hardships of rail travel, acts of infrastructural opportunism that have transformed train carriages into democratic spaces of shared experience, even as the journey navigates a profoundly undemocratic urban landscape.

As a spatial solution, Germiston Station is reimagined as an extension of these activities. The site is rich with existing station functions, such as ticketing counters, offices and the various programmes needed for a station to operate efficiently, all housed within a collection of heritage buildings on its Southern façade. But it remains that, a façade - *a head without a body.* Located at the threshold between Germiston CBD and mining wastelands to its North, the station is characterised by informal trading systems. The intellect of these organic systems enriches the site with socio-economic equity, moving beyond the mono-functionality of transportation infrastructure, a facade of efficiency, to create regenerative public space – *a body in becoming.*

Informed by the intellect of these informal systems, the project looks towards Biomimetic architecture to create a lightweight and far-spanning structure necessary for large transportation nodes – *a habitat for the body in becoming.* A technical investigation considered the integral processes of form and formation in nature, to create a structure that is not only efficient in form, but also equitable in terms of its construction through a hand-based assembly process employing local labourers – *a body for communion during commute, built by the community, enabled through the power of computing.* This structure suspends a trading bridge as public space over the rail tracks, keeping platforms clear of excessive structure – placing people, not structure nor infrastructure, in the foreground.

Project Details

Programme	Mixed-use transportation node Informal trading bridge A place of communion
Address	Railway St, Driefontein 87-Ir, Germiston
Context	Rail renaissance within Johannesburg's mining belt
GPS Coordinates	-26.20958118213868, 28.167771839136336
Departemental Research Field	York Timbers Research Chair
Client	Passenger Rail Agency of South Africa (PRASA)
Theoretical Premise	Humanising rail infrastructure Biomimetic architecture Infrastructural opportunism

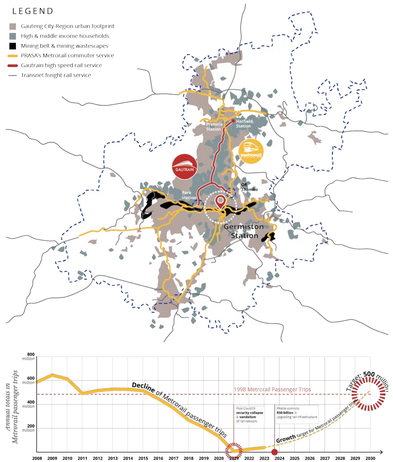


Figure 1: (Author, 2024) based on (Stent, 2022; Taylor, 2020 & Venter, 2023)

Content

PROJECT INTENTION:

Context appropriate **form-finding** for **large scale** urban infrastructural projects keeping **people in the foreground.** *A dance between equity and efficiency.*

PROGRAMMATIC INTENTION

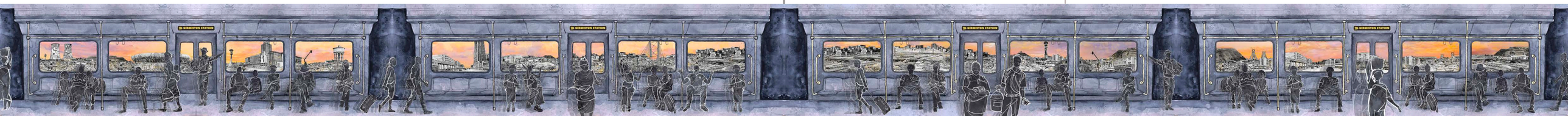
A body in becoming: Investigate rail **station typology** in the context of Johannesburg to understand how its programmatic functioning can act a as a **driver for regenerative public & civic space.**

***EFFICIENCY** of urban mobility & **EQUITY** of station as civic space*

TECHNOLOGICAL INTENTION

Investigate segmented timber shells as a building technology that enables the construction of large spanning vaulted **station morphologies** while employing **low-skilled local labourers, maximising on material capabilities and minimising waste.**

***EFFICIENCY** of structural performance & **EQUITY** of sustainable, participatory construction*



PART 1
Context & Brief

Macro Context

The global surge in private motorised mobility during the 20th century has led to degenerative urban morphologies (Rode, 2013). Characterised by low-density sprawls, the resulting urban forms experience exacerbated congestion, increased road accidents, and heightened pollution levels, resulting in diminished quality of urban habitation (Festus et al., 2020). In academia and governance, there's widespread agreement on the critical role of rail in fostering regenerative cities through multimodal and compact urban morphologies (McLeod et al., 2017; JHB SDF). In the African context, the advantages of rail infrastructure are widely acknowledged (African Union Development Agency, 2019; National Land Transport Act, 2022; Department of Transport National Land Transport Strategic Framework, 2023).

However, the narrative of rail is tainted by its historical role in extracting minerals from a damaged landscape, and funnelling migrants into urban centers as cheap labour, serving as both the literal and figurative vehicle for colonial expansion (Mbem, 2018; Mtembu, 2008: 63). The nuanced legacy of rail infrastructure finds poignant expression in the formation narrative of Johannesburg. Known as "The City of Gold," the city's origins can be traced back to the discovery of gold in 1886 (Tang, 2011). Yet its rapid growth to Africa's largest economy is overshadowed by a history of socio-economic exclusion. Often enforced through industrial infrastructure as a tool for racial segregation, the city's fragmented development finds spatial expression in the entanglement of mining and rail (Mbem, 2018; Pirie, 1992).

Tracing the genesis of Johannesburg reveals a phenomenon where the long, often perilous train journeys undertaken by marginalised populations relegated to the city's peripheries, were enriched with social activities - *acts of communion daring commute* (Laciste, 2023). For decades, these acts have forged hope amid the hardships of rail travel, acts of infrastructural opportunism that have transformed train carriages into democratic spaces of shared experience, even as the journey navigated a profoundly undemocratic urbanscape. Adams (2019) contends that the story of carving equitable spaces from utilitarian infrastructure reflects two defining features of South African life: the experience of migrancy , and the pervasive need for connection—*a catharsis of communion in a moving landscape.*

PART 1
Context & Brief

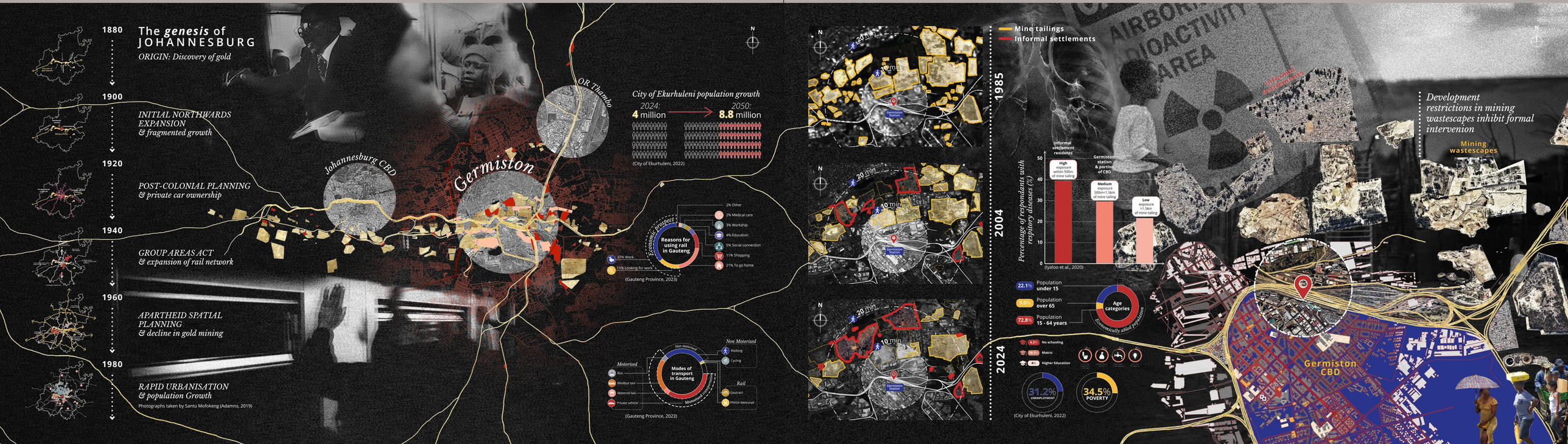
Meso Context

Today, this landscape is still changing. As Gauteng's economy is diversifying (Harrison and Zack, 2012), it is observed that the mine dumps of Johannesburg, *the ghosts of its genesis*, are gradually being remined and disappearing. In its wake, the city's rapid population growth materialises in the form of informal settlements appropriating these wastescapes – another act of infrastructural opportunism. These settling populations, urban prospectors in pursuit of economic opportunity - *the promise of gold* - underscore the pressing need for affordable urban mobility. This mobility serves as a solution that not only reconciles Johannesburg's fragmented past but also prepares for its future. A future at risk of congested transportation arteries and increased road safety accidents amid continual urbanisation (Morapedi & Makhari, 2017; Gauteng Province, 2020)

Occupying these wastelands presents complex challenges. Communities residing within a 500m radius around mine tailings experience worsened respiratory health symptoms, with severity diminishing as distance from the tailings increases (Iyaloo et al., 2020). Inhabitants are intrinsically linked to the legacy of mining by the very air they breathe (Berkovic 2023). The problem deepens as development restrictions in the mine belt, due to instable ground conditions, inhibit various formal interventions aimed at service provisioning in these inhabited wastescapes (Wilkens, 2017: 61). Services both in terms of respiratory health and spiritual health – *services for both mind and body.*

Germiston Station falls right outside of the 500 meter buffer zone, an observation that is true for the majority of rail stations entangled withing the mining belt. Therefore, the station typology, historically used to divide (Mbem, 2018; Pirie, 1992), and can be reimagined as a place from which intervention can take place to become a driver for generative public space. A civic space. *A gateway to the city and its promises of gold.*

To understand how Johannesburg's station typology could drive the regeneration of democratic space, the programmatic intent of this thesis, a closer consideration of the PRASA's planned rail renaissance, the site and its current operations are outlined in the next section.



PART 1
Context & Brief

Micro Context

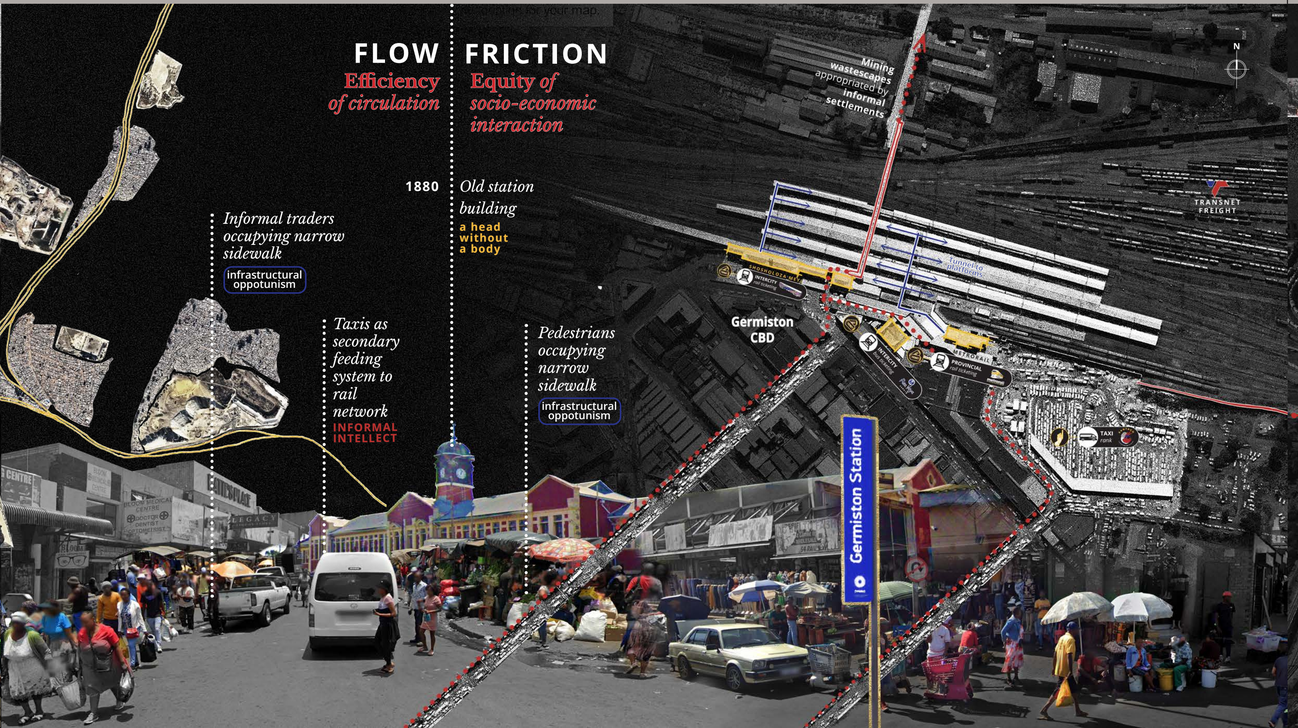
The Passenger Rail Agency of South Africa (PRASA), the nation's main provider of passenger rail services, has faced declining ridership since 2009 (figure 1, page 1). This is due to years of inadequate infrastructure maintenance and a rise in theft and vandalism, especially during the Covid-19 lockdown (Makinana, 2022; Daniel, 2021). However, PRASA is now working to boost ridership significantly by 2030 (figure 1, page 1), achieving key milestones, such as exceeding its capital expenditure targets in 2023 for the first time in a decade (PRASA, 2023: 52). Notably, the recently reopened Leralla-Germiston line, renovated with nearly R600 million, serves approximately 10,000 passengers daily (Nwadzule, 2023). Since mid-2021, demand for passenger rail has surged by 215% (Stats SA, 2023: 5).

PRASA's efforts to establish rail as the backbone of sustainable and affordable urban mobility can be observed at Germiston Station. A micro analysis reveals that the site contains a complex series of existing and semi-operational station functions, such as ticketing counters, offices, storage, employee facilities and everything else needed for a station to operate efficiently, all housed within a collection of heritage buildings on its Southern façade. But it remains that, a façade - *a head without a body*. And this head houses the station's utilitarian and operational programmes - *the organs of efficiency.*

Formalised functions exist in conjunction with the informal, organic systems that have sprouted along transportation arteries to breathe life into the site - *a body in becoming*. Here, trading and ritual, *the organs of equity*, has taken to the streets in another act of infrastructural opportunism observed at meso scale.

The coexistence of formal and informal functions can be understood as a spatial phenomenon of *flow and friction*. *Flow* represents the efficiency of circulation and utilitarian functions required at busy transportation nodes. Conversely, *friction* represents the opportunity to foster equity through programmes that stimulate socio-economic interaction.

Refer to your map

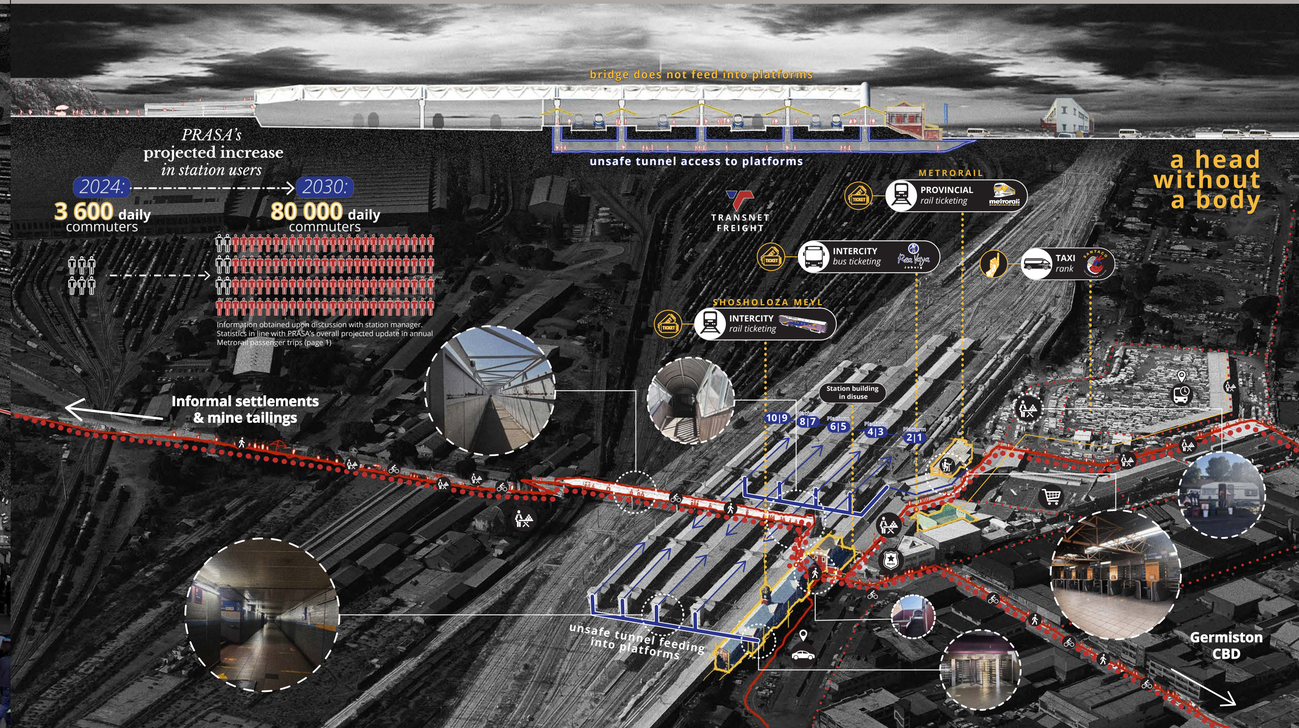


PART 1
Context & Brief

Transport Systems

A closer analysis of Germiston Station's transportation systems reveals a mix of formal and informal networks. Bus and taxi services successfully act as secondary feeders to the Metrorail network. However, accessing the rail platforms poses a challenge for users. The pedestrian bridge, which serves as the only entry point to from the mine dumps to Germiston CBD, does not connect directly to the platforms. An urban prospector from the informal settlements to the North must cross this bridge, buy a ticket on the Southern side, and then navigate an underground tunnel to reach the platforms. This layout prioritises machinery over pedestrian experience, relegating foot traffic to an inconvenient route. With PRASA projecting a 22-fold increase in station occupancy*, congestion is imminent—a spatial problem of *flow and friction*.

*Information obtained upon site visit and discussion with station manager, which is in line with PRASA's projected uptake in passenger trips (figure 1, page 1)



PART 1
Context & Brief

Precedents

To gain clarity on placing people in the foreground of large scale transportation infrastructure, the project considers Shinjuku Station, the world's busiest railway station (Chowdhury et al., 2022). In this analysis, two things become clear. Firstly, a successful station is not just a facade, the station head, *the organs of efficiency*, requires a body to embody the *organs of equity*. In the case of Shinjuku Station, socio-economic interaction - *friction* - materialises in the form of formalised retail nodes and public space running parallel to transportation veins, all seamlessly connected with pedestrian networks. While Germiston Station also has some convenience retail in close proximity (page 6), the opportunity exists to integrate the prevalence of informal markets into this *body in becoming*, enriching the station with a regional character.

Secondly, a successful station does not exist in isolation, but should be understood as network of nerve endings that extends into and nourishes the city. Important to note is the relevance of other transportation modalities to serve as secondary feeding networks. If transportation stops working, the city stops working. If the station is healthy, *unified in body and mind*, the city thrives.

Understanding a building as an extension of the public streetscape is also observed in the Watershed by Wolff Architects (Wolff Architects, n.d) . While this project's context is different to that of Germiston Station, there is still value in understanding that successful public space, in this case a formalised market space, requires a unifying element to create spatial fluidity. Simply put, the industrial scale of the shed's far-spanning roof acts as a unifying element to the market spaces below, generating public space through the dissolution of boundaries between interior and exterior realms. *A shell for the organs of equity.*

Conceptualising a large public building as a *body, a shell or a vessel that houses fluid space within* is also observed at Warwick Junction in Durban (eTafuleni, 2020). The project becomes an urban scale infrastructural shell both in the form of a series of large industrial scale roofs, and the inhabited trading bridge. The key observation here is that large scale urban infrastructural projects in this context require a degree of flexibility, allowing for the organic and informal systems of the city to inhabit it on its own terms in the spirit of *infrastructural opportunism.*

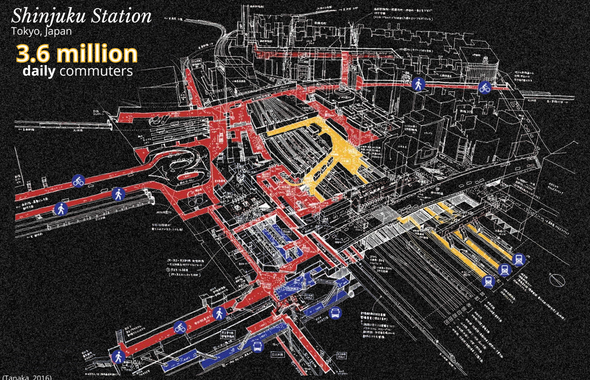
PART 1 concludes with an understanding that, in order to place people in the foreground of urban infrastructure, a large, flexible and fluid space is necessary—a kind of vaulted architecture that becomes a habitat for the organic mix of programmes within, bridging the divide between *efficiency and equity, interior and exterior, formal and informal, form and formation.* Bridging the divide *between station head and body.*

PART 2 will present segmented timber shell structures as an innovative building system that can be contextualised within the South African built environment, becoming a technological support to this programmatic aim.

PROJECT INTENTION:

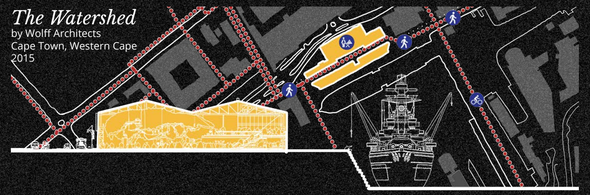
Context appropriate **form-finding** for **large scale** urban infrastructural projects keeping **people in the foreground.** *A dance between equity and efficiency.*

Shinjuku Station
Tokyo, Japan
3.6 million
daily commuters

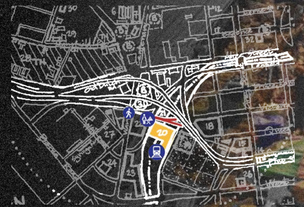


(Tanaka, 2016)

The Watershed
by Wolff Architects
Cape Town, Western Cape
2015

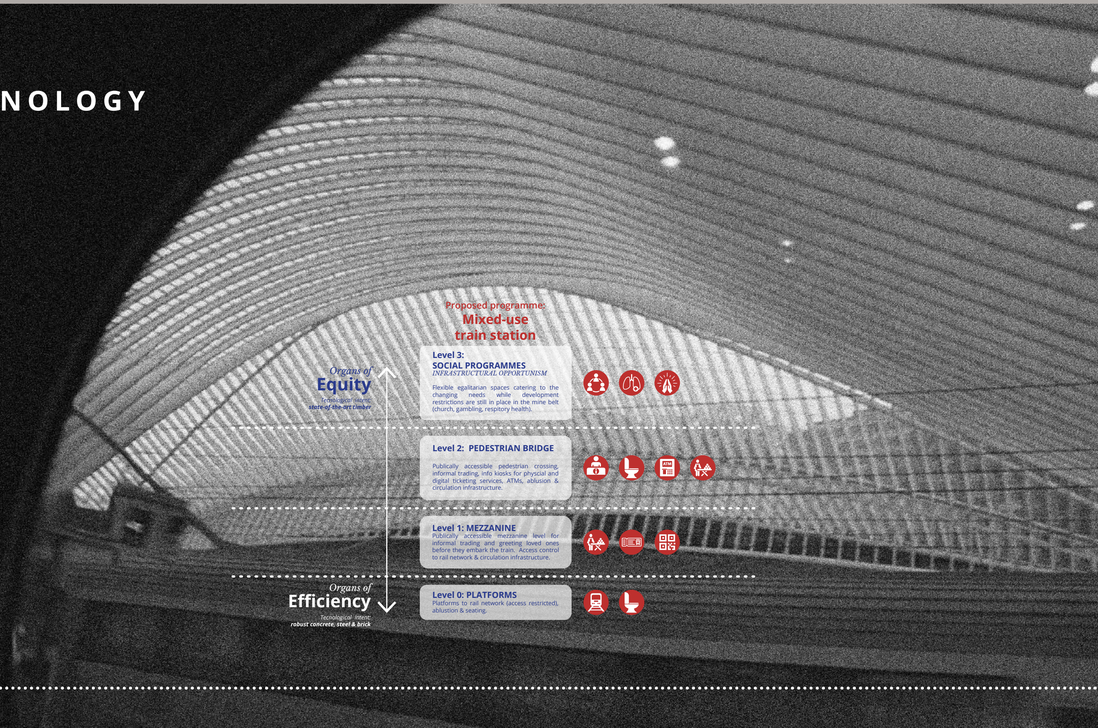


Warwick Junction
Durban, KwaZulu Natal
460 000
daily commuters



PROGRAMME

TECHNOLOGY



Liège Guillemins station
by Santiago Calatrava
Liege, Belgium
2009

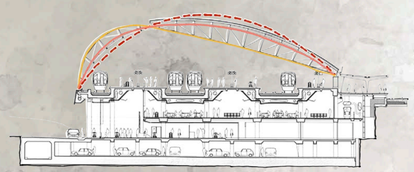
PART ② *Form-Finding*

"In biology material is expensive but shape is cheap" (Vincent 2009: 78).

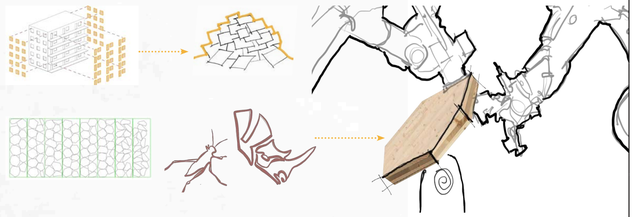
This observation captures the essence of biological structures. Oxman (2010: 41-44) contends that the natural world demonstrates an exceptional ability to utilise material and energy economically, often through the evolved ingenuity of complex forms and their growth processes. The high level of functionality and performative capabilities of these natural systems result from the sophisticated way energy and material are negotiated between the system's internal requirements, such as its genetic coding, and the external environmental force acting upon it. This negotiation ensures that the system is optimised for survival within its habitat, resulting in intricate structures where form and formation are unified (Menges 2011: 72).

In contrast, in the contemporary built environment, the realisation of architectural intent typically follows a separate relationship that prioritises the definition of form over its subsequent construction process. The the thin continuous concrete shell represents this separation of form and formation. Structural efficiency is achieved by leveraging concrete's exceptional performance under compression, which mirrors gravitational forces along its surface curvature (Noh 2005: 1420). However, the constructability of concrete shells, its formation, has consistently been their most difficult aspect (Krieg & Menges 2022: 71). Notably, its formwork is both material and labour-intensive (Schumacher 2016: 70). Fitness of formation fell victim to form.

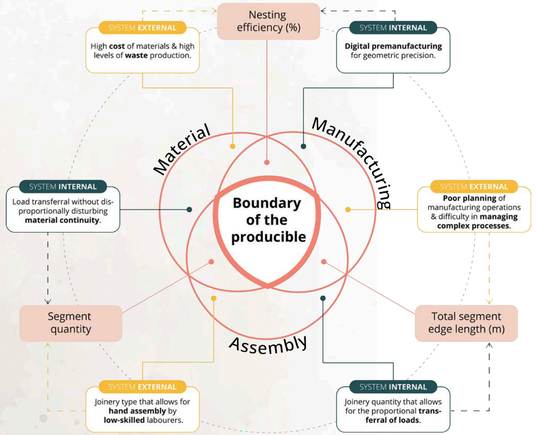
Integrative computational design (ICD) and Biomimetics have emerged as an approach that seeks to unify form and formation through a consideration of innovative design, manufacturing and fabrication methods with the use of bio-based materials to emulate the performative capabilities of natural structures (Krieg & Menges 2022: 3). Simply put, ICD is an approach to architectural form-making that not only considers performance in terms of structural capabilities, but performance in terms of context specific construction processes as structures can be assessed and optimised across various dimensions. This includes, but is not limited to, geometry, environmental forces, social data and economic constraints (Tedeschi & Wirz 2014: 19). *Form and formation are optimised simultaneously through the power of simulation.*



Waterloo International Railway Station
by Grimshaw Architects & Sir Alexander Gibb & Partners
London, United Kingdom
1993



Portuguese National Pavilion
by Álvaro Siza Vieira
1998

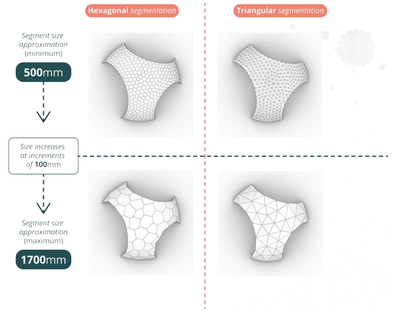


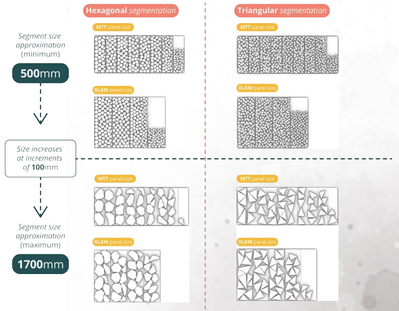
BUGA Wood Pavilion
by ICD Stuttgard
Heilbronn, Germany
2019

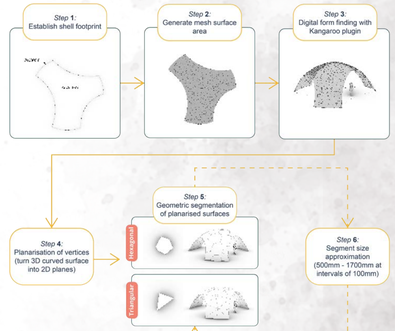
PART ② *Form-Finding*

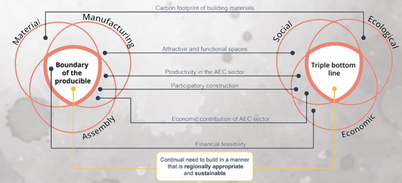
Segmented timber shells, as seen in the BUGA Wood pavilion (page 9, bottom left), represent a unification of form and formation. This structural typology holds great potential for lightweight construction systems with far-spanning capabilities, exemplifying the biological pursuit of maximum efficiency with minimal resources (Oxman 2010: 41). Building materials fit for this type of construction must offer an optimal weight-to-strength and stiffness ratio (Bletzinger & Ramm 2001: 2053). Engineered timber products boast some of the highest strength-to-weigh ratios and the lowest environmental impact among load-bearing materials (Wikstrom 2023: 177). These products are most readily available in straight planar elements, informing a standardised and economic manufacturing process leveraging the most digitally advanced subsector within the AEC industry. The result is simple yet geometrically unique segments, allowing for on-site assembly of prefabricated modules at a pace much faster than in-situ construction (Bechert, Sonntag, Aldinger & Knippers 2021: 4815). As approximations of 3-dimensional curved geometries with the use of 2-dimensional planar timber elements, segmented shells integrate the structural performance of catenary curves with the fabrication efficiency of design for manufacturing and assembly (DfMA) workflows (Bechert et al. 2021: 4814–4815). Form and formation are finely attuned.

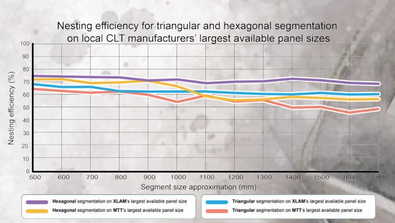
The formation processes of a biological organism is tied to its context, *its habitat* (La Magna et al., 2013: 27). Therefore, the project endeavours to optimise the construction of segmented shells in the South African context based on the nations regional material, manufacturing and assembly conditions. Within each of these three realms, the internal structural requirements of a timber shell is considered in conjunction to the external environmental conditions of the South African building industry. Simply put, an organism's formation intersects its internal genes and external environment (Menges 2011: 72). The mapping of internal and external considerations for the construction of timber shells means that the intersection of these qualitative themes can be investigated as quantitative parameters in a data-driven design process. This process leads to the optimisation of segmentation size and geometry, *the puzzle pieces used to hand-assemble the shell*, tailored to its context.

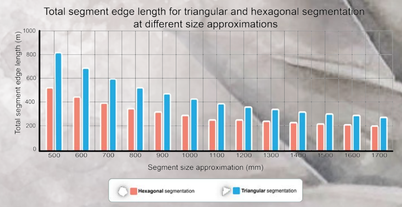


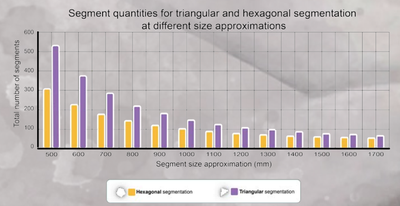












PART ② *Form-Finding*

From mono-parametric (efficiency) to multi-parametric (equity) optimisation.

In nature, curved surfaces are segmented with voronoi geometries -*hexagons and triangles* (La Magna et al. 2013: 32). Data was obtained for each parameter by simulating various shells as different segment sizes with the two voronoi geometries. The data was then mapped onto a framework (below) with the centre point representing the optimal for each dataset. The full study scope, methodology and relevance of each parameter can be accessed here: https://drive.google.com/file/d/1oU8WWweF6Cq4BEpO4sp35lzYhknEXwy8/view?usp=sharing

As a summary, it is observed that what is optimal in terms of nesting efficiency, *how well segments fit onto standardised cross-laminated timber panels of South African manufacturers*, contradicts what is optimal in terms of segment edge length, *a proxy for robotic machining intensity*.

Simply put, smaller segments nest better, but lead to longer edge lengths and a greater quantity of segments. Longer edge lengths imply greater fabrication complexity, a regional constraint. Moreover, smaller segments might nest better and reduce waste, yet result in a greater quantity of segments that will make it increasingly difficult to cut, label, manage and assemble these parts, making its less feasible to employ low-skilled labourers dependant on the construction industry for job creation.

The value of this study lies in its holistic approach to optimisation. Considering the contradictions in terms of what is optimal for nesting efficiency versus what is optimal for segment quantity and total edge length, leads to distilling a regionally appropriate segmentation size and geometry - *hexagons with an edge length of 800mm to 1000mm.*

This investigation reveals the intricacies between materiality, resourcefulness, affordability, structural integrity, parts availability, fabrication tools, assembly, and skills - relationships that have always been deeply understood by skilled craftspeople (Menges et al. 2016: 6). Form and formation are not solely a function of physical force. It is not mono-parametric. Rather, it results from the negotiation between the technicalities of fabrication *efficiency*, the computable, and the socio-economic forces that define the conditions of its *equitable* construction, the incomputable. By leveraging ICD tools, architects can reimagine their role in the digital era akin to that of the master carpenter. In this capacity, the architect becomes the master of the data, computationally mediating between what is optimal in terms of *form versus formation*. Efficiency and equity converge, resulting in novel form-making using hand-based labourers.

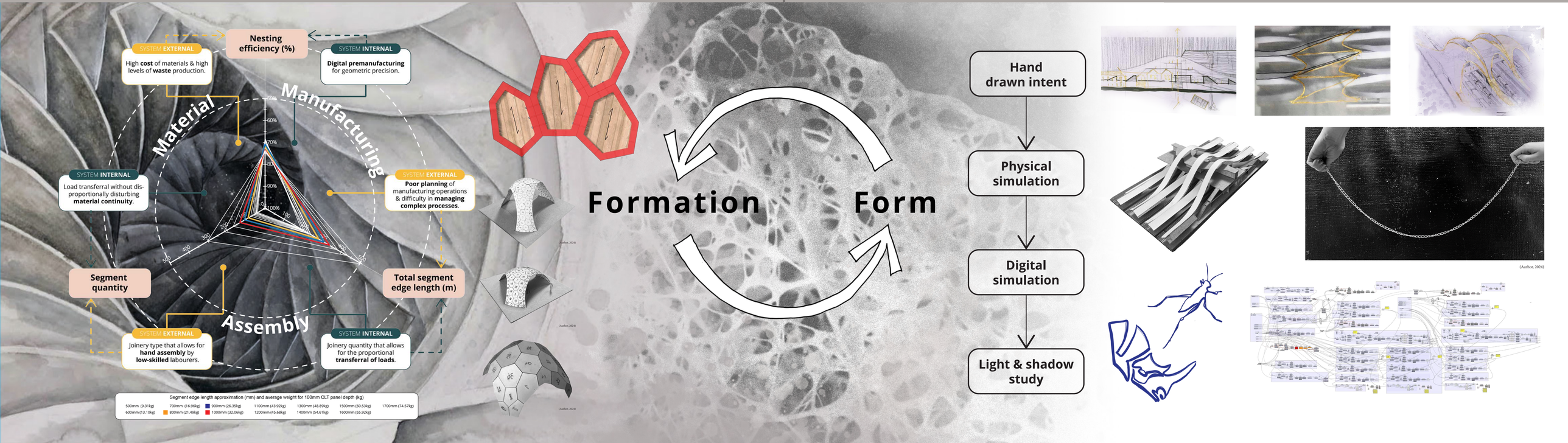
PART ② *Form-Finding*

With clarity on a regionally appropriate segmentation size and geometry for large vaulted spaces - *how to build doubly curved surfaces with South African labourers, manufacturers and locally grown engineered timber* - the project ventures on a form-finding journey, the main intent. This follows a bottom up approach where the possibilities of *efficient* and complex geometries result from an understanding of its *equitable* construction through segmentation and hand-assembly of engineered timber elements.

Important to note is the hybrid approach to form-finding that combines traditional drawing and physical modelling methods in conjunction to digital simulation techniques and algorithmic scripting principles.

PROJECT INTENTION:

Context appropriate **form-finding** for **large scale** urban infrastructural projects keeping **people in the foreground**. *A dance between equity and efficiency.*



PART ②
Form-Finding

Shadow Study

The pursuit of placing people, not structure nor infrastructure, in the foreground of this project, means that the form-finding process is entangled with a light and shadow study. This serves as a proxy for safety and user comfort. Heinzelmann (2018: 4) asserts that a connection to the temporal nature of light and shadow remains an important aspect of the user experience and spatial quality of large roof footprints. This is also an important design consideration in Calatrava's approach to station design (Alvarez & Randl 2015: 15).

Thus, the form-finding journey focuses on optimising direct daylight and shadows according to peak occupancy hours within a day, and season.

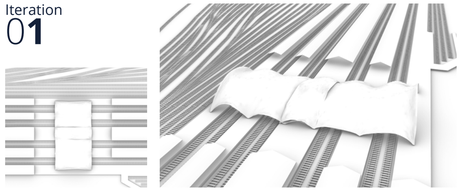
This investigation is based on the common assertion that building form should encourage direct sunlight in winter, and maximise on shading in summer (Beckers & Beckers 2008: 2–4). SANS 10400 does not specifically outline daylight hour standards for winter and summer. However, energy efficiency and climate-responsive design principles, such as managing heat gain in summer through shading, and maximising heat retention in winter through sunlight, are covered in SANS 10400 XA.

Thus, initial massing exploration, limited to the relationship between daylight, shadows, time and form, serves as a proxy for thermal comfort and energy performance.

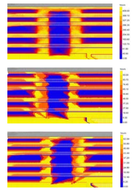
Light & Shadow Study Methodology

Geometry is algorithmically generated and analysed with Ladybug, an environmental analysis plugin (Ladybug Tools n.d.). A tool is scripted using a local EPW weather file, which enables the output of direct sunlight hours on the roof geometry with a colour map. Purple pixels represent surfaces with more shadow hours while yellow pixels represent surfaces with the most daylight hours. The performance of each iteration and its resulting colour map is assessed using a checklist of indicators.

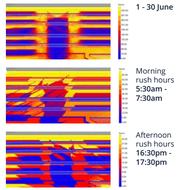
Iteration 01



SUMMER



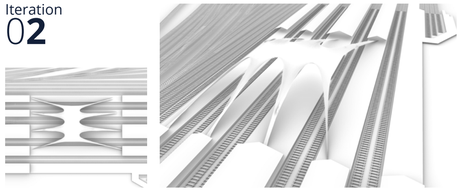
WINTER



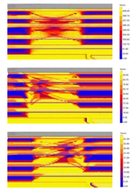
	0	1	2	3	4
Seasonal discrepancy in daylight hours	●				
Morning light performance	●				
Afternoon light performance					●
Flow of light between existing and new	●				
Elegant form	●				

Score **4**

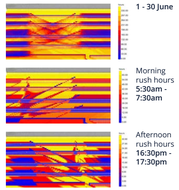
Iteration 02



SUMMER



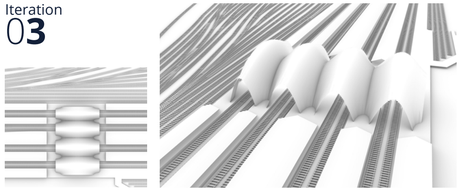
WINTER



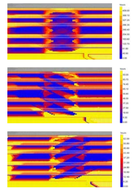
	0	1	2	3	4
Seasonal discrepancy in daylight hours	●				
Morning light performance				●	
Afternoon light performance	●				
Flow of light between existing and new		●			
Elegant form	●				

Score **4**

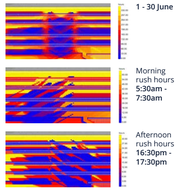
Iteration 03



SUMMER



WINTER



	0	1	2	3	4
Seasonal discrepancy in daylight hours	●				
Morning light performance			●		
Afternoon light performance	●				
Flow of light between existing and new	●				
Elegant form		●			

Score **3**

PART ②
Form-Finding

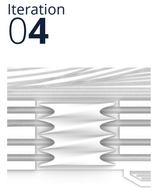
"The essence of technology is by no means anything technological."
(Heidegger 1977: 9)

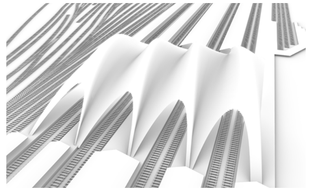
Performance Indicators

In short, these indicators are focused on increasing daylight hours during the station's morning rush hours, while optimising for shade during afternoon peaks. It considers daylight hours during seasonal changes, meaning that daylight is preferred in winter months while shading is preferred in summer months.

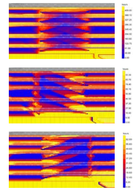
However, relying solely on a data-driven methodology has the risk of creating high-performing structures that remain intuitively displeasing to the human senses (Carpo 2017). *Reconciling the computable and the incomputable*, the study includes the author's design intuition to ensure that the form is not only *efficient* in terms of its relationship to daylight and shadow, but also *equitable* in terms of its overall elegance and sculptural quality. This underscores the importance of a mixed-method form finding methodology (page 12 & 16) where hand drawing and physical model making should remain the at the forefront of design intent before employing simulation tools. *Technology is not a means in itself but an enabler.*

Iteration 04

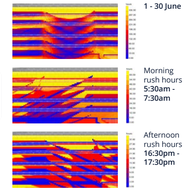


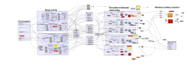


SUMMER



WINTER

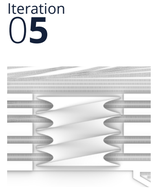


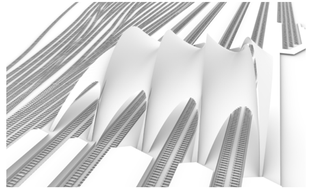


	0	1	2	3	4
Seasonal discrepancy in daylight hours				●	
Morning light performance					●
Afternoon light performance			●		
Flow of light between existing and new	●				
Elegant form			●		

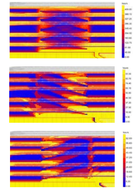
Score **7**

Iteration 05

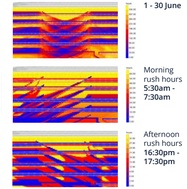




SUMMER



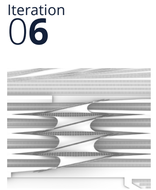
WINTER

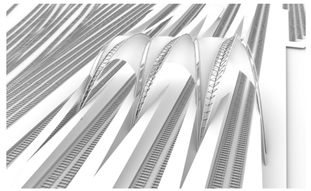


	0	1	2	3	4
Seasonal discrepancy in daylight hours				●	
Morning light performance				●	
Afternoon light performance		●			
Flow of light between existing and new		●			
Elegant form		●			

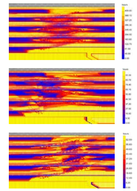
Score **9**

Iteration 06

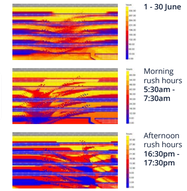




SUMMER



WINTER



	0	1	2	3	4
Seasonal discrepancy in daylight hours			●		
Morning light performance				●	
Afternoon light performance	●				
Flow of light between existing and new				●	
Elegant form			●		

Score **9**

Reflection on Iteration process

Iteration 1-3 employed algorithmic scripting principles that simulates a cloth hanging in the positive z direction to create different types of catenary vaults. However, with catenary geometries, it can be difficult to depart from a repetition of the typical vault (iteration 3), meaning that the building might lack contextual responsiveness.

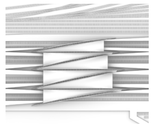
From iteration 4 onwards, more attention was given to create a form that weaves itself into the linear topological layout of the existing station platforms. This resulted in a greater and more interesting degree of interweaving between daylight and shadows.

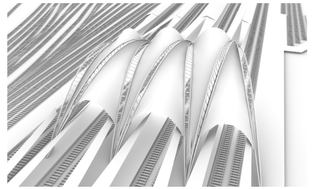
An unexpected outcome of this process is the amount of scripting principles that had to be learned and applied in order to achieve the desired results in terms of light and shadow. The scripting intentions departed from a typical catenary mesh simulation (iteration 1-3) to include lofting over catenary arches (iteration 4-5). While this approach improved seasonal discrepancy of light versus summer and winter, there was still opportunity to make these forms more elegant and responsive to the topological layout of the existing platform pitched roofs. This led to an exploration of minimal surfaces as another digital simulation approach, which is based on Frei Otto's physical simulations using soap films (iteration 6-8) (Emmer 2015).

A simple light and shadow study resulted in a form that is completely different from any preconceived idea of what the shell might have looked like at the project onset. Iteration 8 achieves light to enter the roof in a seasonally appropriate way. This means that direct light falls onto uninhabitable train tracks during summer months, while penetrating deeper to warm and illuminate habitable platforms during winter months.

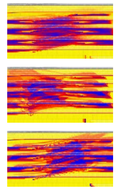
Another unexpected outcome of this form-finding process is the arrival of a form (iteration 8) that can become inhabited by the recently banned programmes on PRASA's train carriages (page 21). The hyperbolic paraboloid allows for the placement of programmes inside the actual shell, becoming more than just a roof, but truly *a body in becoming - another act of infrastructural opportunism.*

Iteration
07





SUMMER

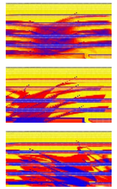


1 - 31 Dec

Morning rush hours 5:30am - 7:30am

Afternoon rush hours 16:30pm - 17:30pm

WINTER



1 - 30 June

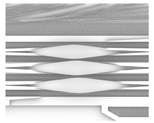
Morning rush hours 5:30am - 7:30am

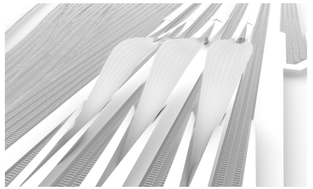
Afternoon rush hours 16:30pm - 17:30pm

	0	1	2	3	4
Seasonal discrepancy in daylight hours				●	
Morning light performance				●	
Afternoon light performance	●				
Flow of light between existing and new				●	
Elegant form			●		

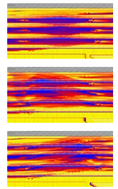
Score **11**

Iteration
08





SUMMER

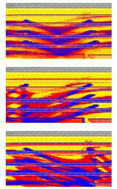


1 - 31 Dec

Morning rush hours 5:30am - 7:30am

Afternoon rush hours 16:30pm - 17:30pm

WINTER



1 - 30 June

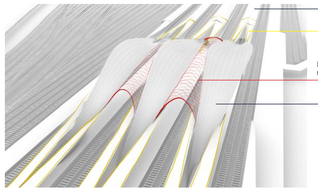
Morning rush hours 5:30am - 7:30am

Afternoon rush hours 16:30pm - 17:30pm

	0	1	2	3	4
Seasonal discrepancy in daylight hours				●	
Morning light performance				●	
Afternoon light performance	●				
Flow of light between existing and new					●
Elegant form				●	

Score **13**

Reflection
& next steps

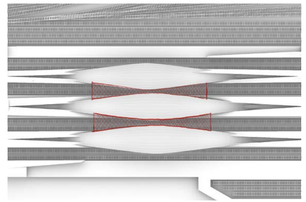


Existing platform roofs

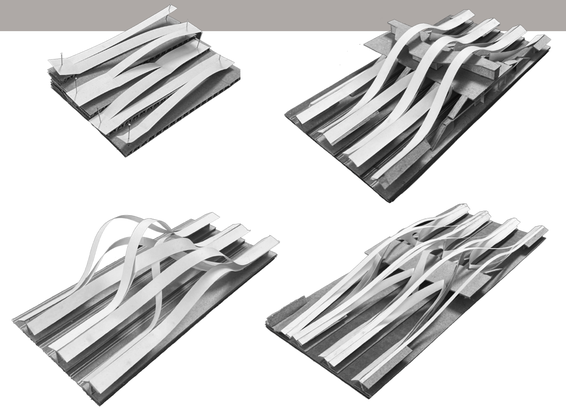
New platform roofs

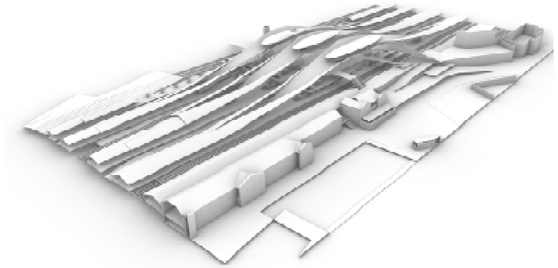
Introduction of gridshell to allow light to fall onto train tracks, but create more shade for afternoon light (tectonic)

Iterated shell:
structural behaviour of a hyperbolic parabaloid. Next step is to place programmes on top of this shape. As trains has been inhabited by different programmes, so can this shell shape can become more than just a roof. The iterative process unextectedly produced a shell shape that can be inhabited, expressing the phenomenon of *infrastructural opportunism*



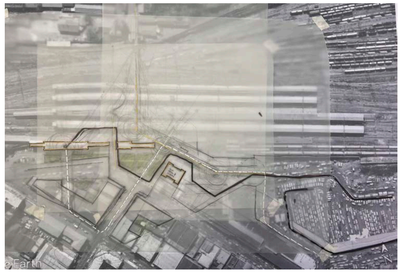
Form-finding intent:
Weaving with the existing linear *- flow & efficiency -* topological layout of the platforms and existing pitched roofs to create a body *- friction & equity.*

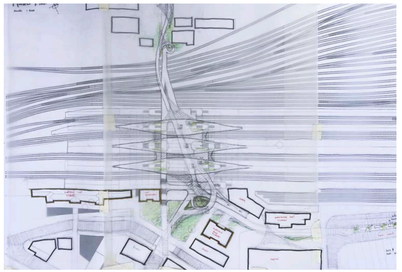


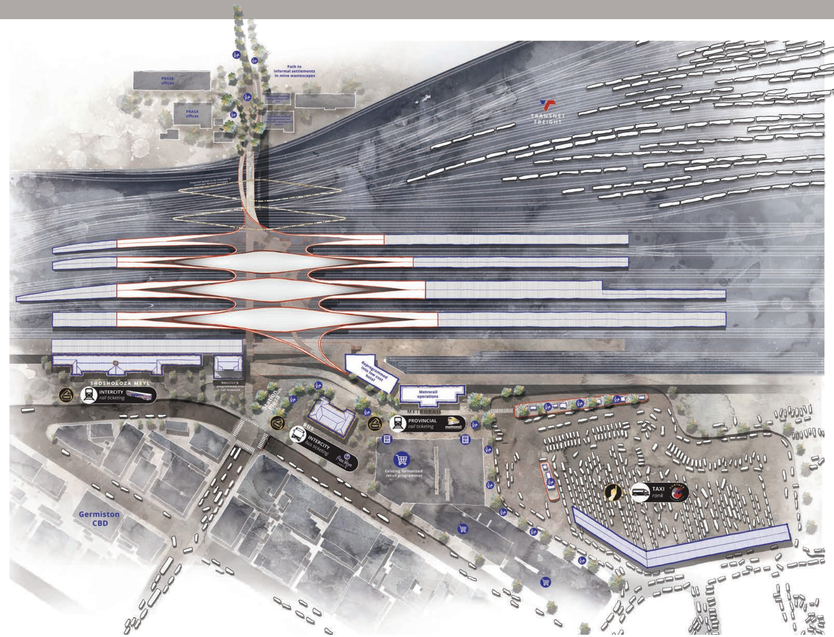


PART 3
Spatial Outcomes

Master Plan



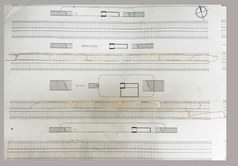


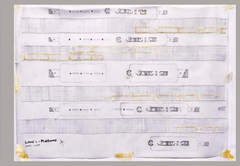


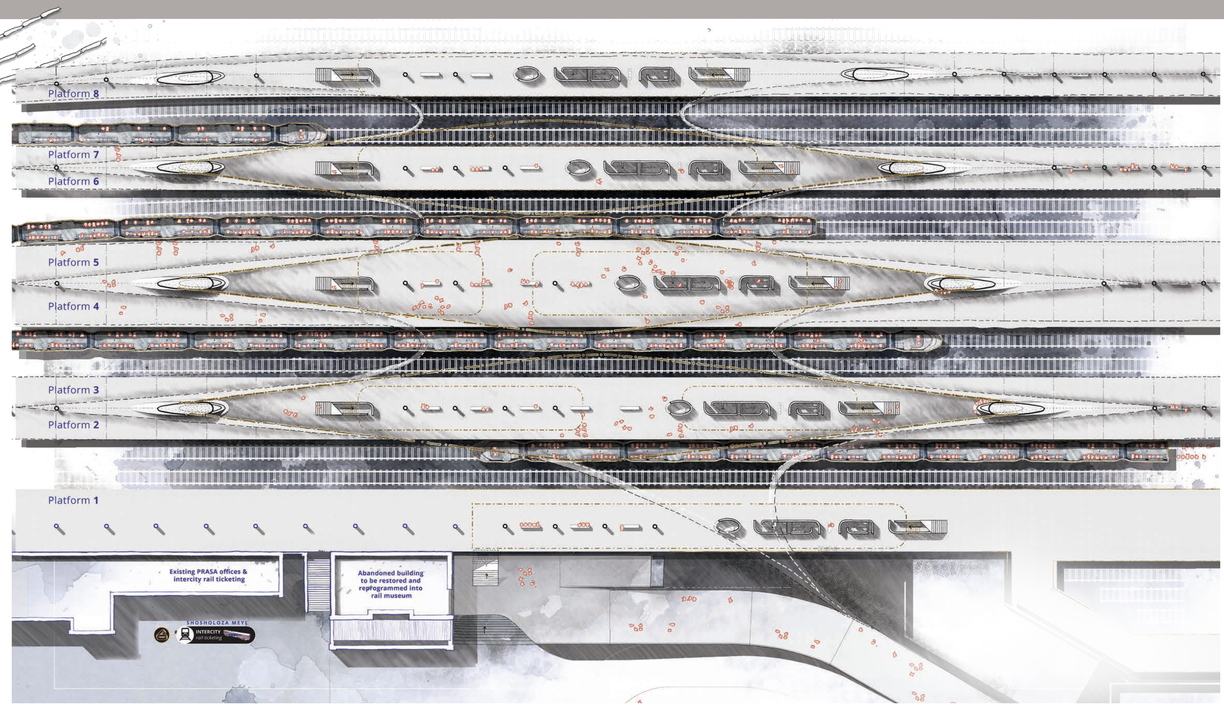
Map of deconstructed buildings (red) to create a station plaza on the Southern facade. Bricks from this process to be used to build ablution blocks on platform and bridge level. Excess materials to form part of circular material economy.

PART 3
Spatial Outcomes

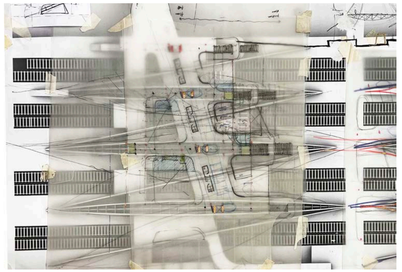
Platform Plan

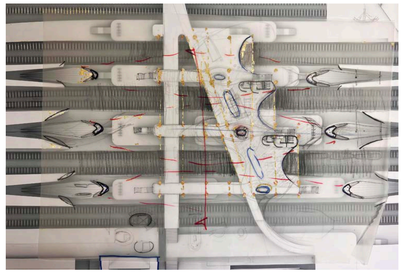


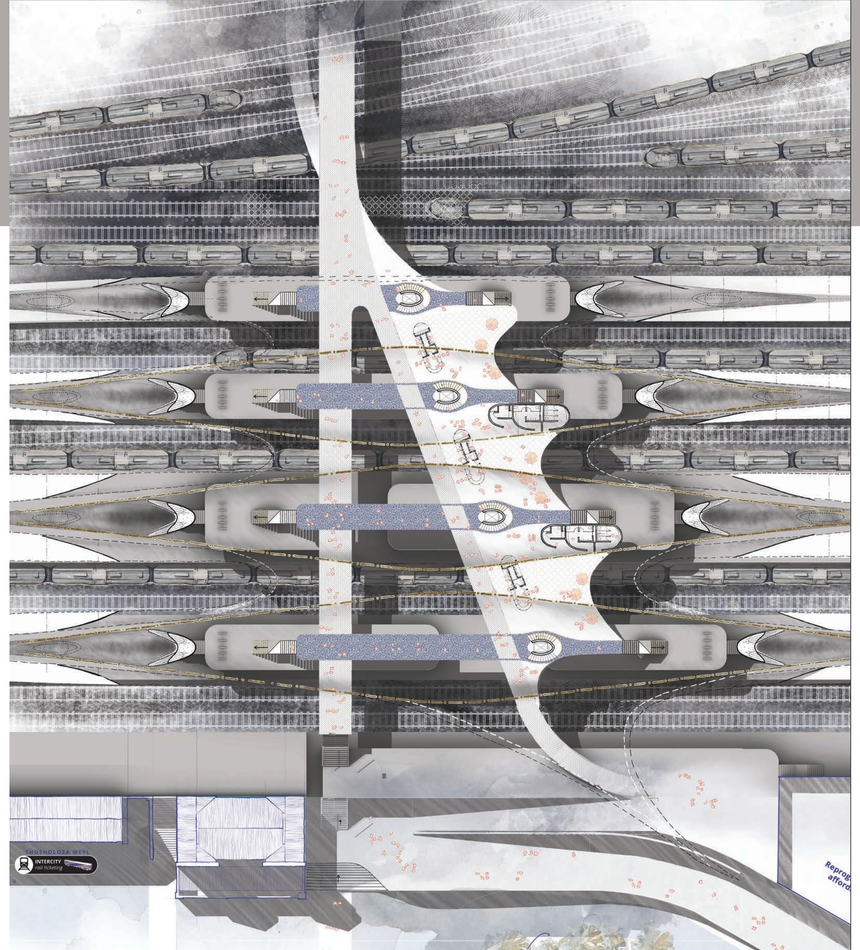




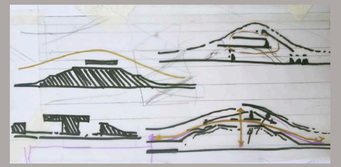
Public Trading Bridge

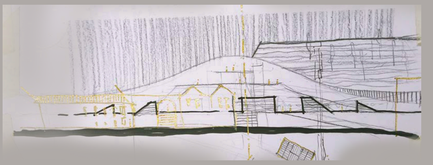


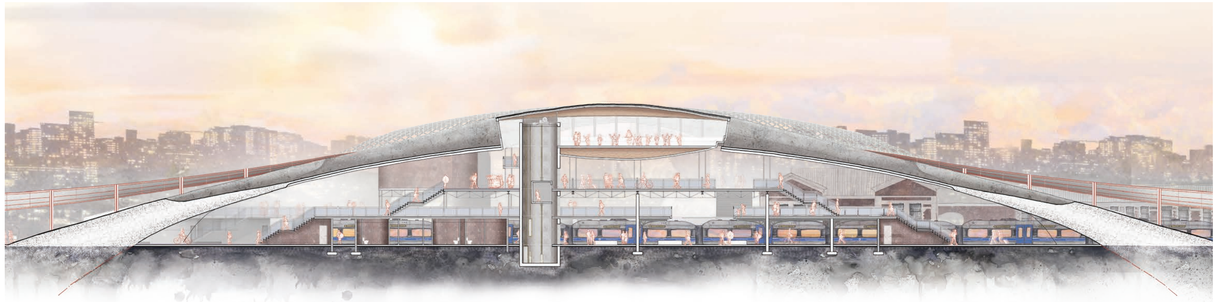


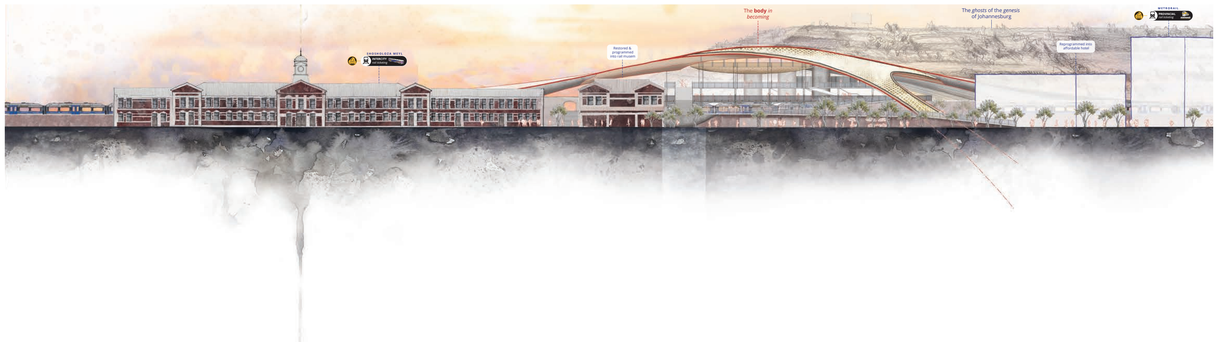


Section A-A & Southern Facade

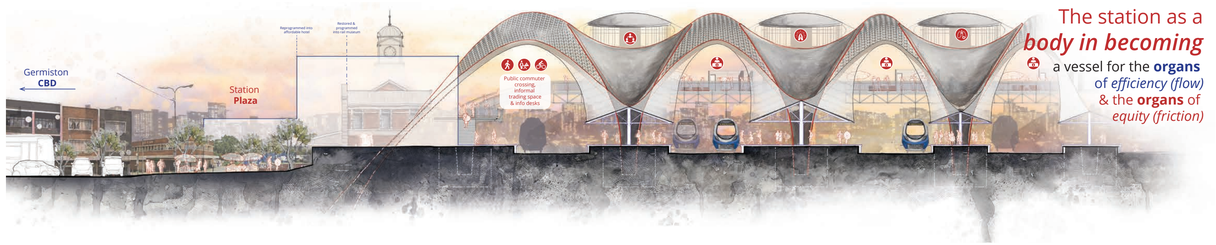




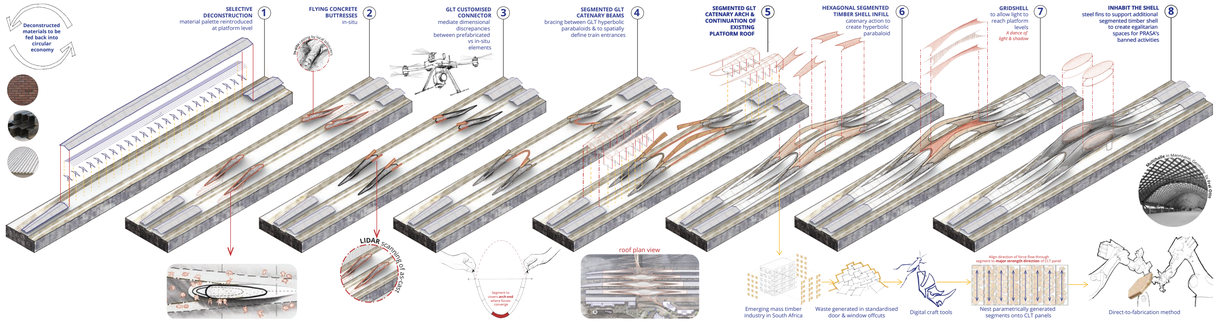




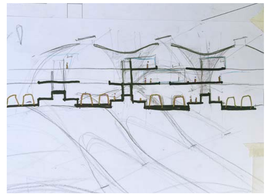
Section A-A & Assembly

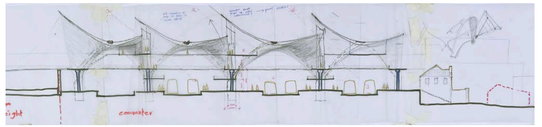


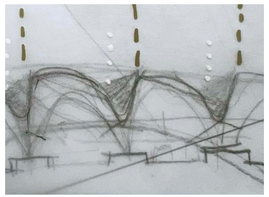
The station as a
body in becoming
a vessel for the **organs**
of efficiency (flow)
& the **organs** of
equity (friction)

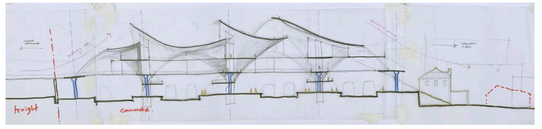


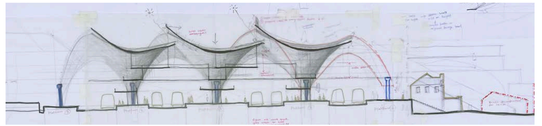
Section B-B

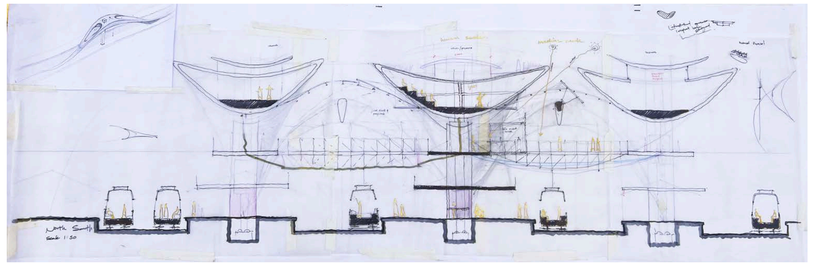


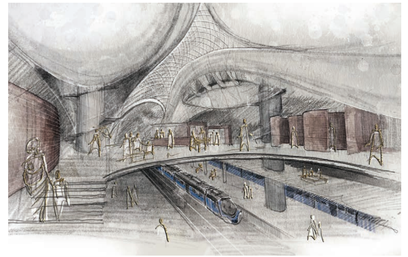












Critical Reflection

PROJECT INTENTION:

Context appropriate **form-finding** for **large scale** urban infrastructural projects keeping **people in the foreground.** *A dance between equity and efficiency.*

PROGRAMMATIC INTENTION

A body in becoming: Investigate rail **station typology** in the context of Johannesburg to understand how its programmatic functioning can act a as a **driver for regenerative public & civic space.**

***EFFICIENCY** of urban mobility & **EQUITY** of station as civic space*

TECHNOLOGICAL INTENTION

Investigate segmented timber shells as a building technology that enables the construction of large spanning vaulted **station morphologies** while employing **low-skilled local labourers, maximising on material capabilities and minimising waste.**

***EFFICIENCY** of structural performance & **EQUITY** of sustainable, participatory construction*

In natural systems, a single optimal solution does not exist. La Magna et al. (2013: 27) assert that the variety observed within natural habitats suggests that different solutions may perform more optimally in different scenarios.

Context appropriate form-finding is not a pursuit of a single answer, an optimal form. It is about revealing the diversity of options through a mixed method approach of traditional drawing, model making, and digital simulation and assessment tools. Context appropriate form-finding is about embracing a new paradigm of architectural production in the digital era. Herein lies the evolving role of the architect to the computational designer - *the form-finder.*

In the case of large scale urban infrastructural projects, it is about sculpting and molding the existing into the new. Being bold through a consideration of the machine scale, while simultaneously being sensitive to the human scale.

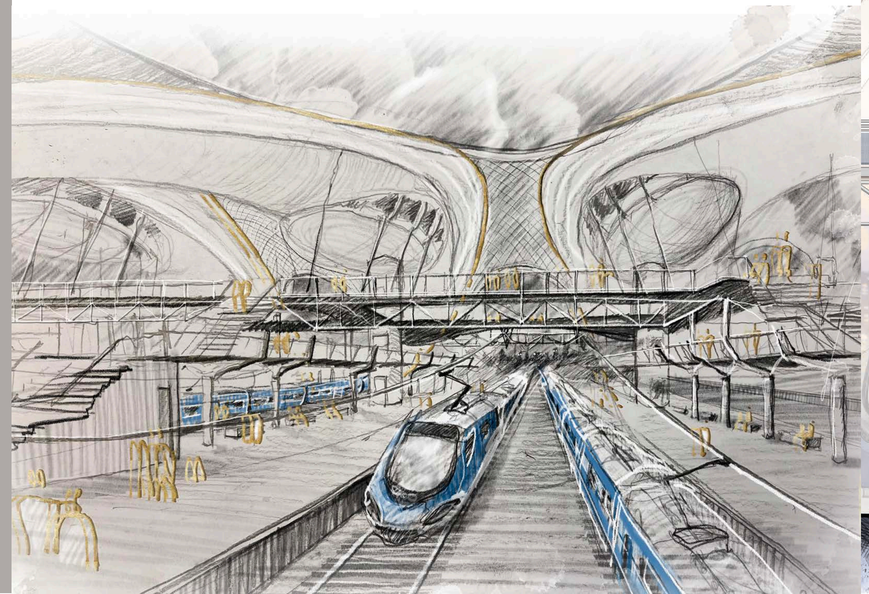
Reflecting on the integral processes of form and formation in the biological world, it is about understanding its construction before any preconception of form. Iterating form through daylight simulation and assessment - *inviting it to dance with light and shadow* - led to a form that can become inhabited by PRASA's banned social activies of *communion during commute.* Thus, the *body in becoming* became more than a roof. It became a habitat. An architectural expression of *infrastructural opportunism* itself.

And in the spirit of infrastructural opportunism, transforming utilitarian carriages into civic spaces for a mere moment in time, this journey sought to redefine what a rail station in the context of Johannesburg can be.

It is not a facade, it is not a face. It does not have to continue to serve the legacy of Apartheid as a belt of infrastructural division. It does not have to reduce people to the background in pursuit of efficiency. A station is not a series of platforms or a narrow mono-functional pedestrian bridge. A station is not a church, a clinic or a gambling house. A station is not an informal market, ticketing kiosks, ablution or vertical circulation. These are merely parts of a whole - *organs of the body.*

A station is the city itself. A station is affordable mobility. A nucleas where all scales come together - *a gateway to the promise of gold.* A station is a heartbeat, a network of veins stretching into a segregated cityscape to foster and feed economic growth and inclusion, the lifeblood of a functioning democracy. A station is unified in body and mind, in programmes - *organs* - of efficiency and of equity.

A station bridges the utilitarian and the divine.



References

Adams, T. (2019) 'The big picture: Santu Mofokeng's train church', The Guardian, 17 February. Available at: https://www.theguardian.com/artanddesign/2019/feb/17/santu-mofokeng-train-church-soweto-south-africa-the-big-picture (Accessed: 6 November 2024).

Alvarez, A. and Randl, C. (2015) 'Unknown Shadows Associations Between Nature, the Human Body, and Architecture'.

AU (African Union) (2019) Towards the African Integrated High-Speed Railway Network (AIHSRN) Development.

Bechert, S. et al. (2021) 'Integrative structural design and engineering methods for segmented timber shells-BUGA Wood Pavilion', in. Structures, Elsevier, pp. 4814–4833.

Beckers, B. and Beckers, P. (2008) 'Optimization of daylight in architectural and urban projects', in. Comunicación presentada en: Second International Conference on Multidisciplinary Design Optimization and Applications, Guijón, España.

Berkovic, S. (2023) 'Heritage, legacy and loss in a city built on gold', The Mail & Guardian, 17 February. Available at: https://mg.co.za/thought-leader/2023-02-17-heritage-legacy-and-loss-in-a-city-built-on-gold/ (Accessed: 6 November 2024).

Bletzinger, K.-U. and Ramm, E. (2001) 'Structural optimization and form finding of light weight structures', Computers & Structures, 79(22–25), pp. 2053–2062.

Carpo, M. (2017) The second digital turn: design beyond intelligence. MIT press.

Chowdhury, T., Bari, Q.H. and Mukherjee, D. (2022) 'Advances in facilities prevail in mass transit railway stations in Asian cities, including Dhaka: a review'.

Daniel, L. (2021) 'Shock new numbers show how SA's train service went off the rails – even before Covid hit', Online. Available at: https://www.news24.com/news24/bi-archive/travel-survey-shows-how-sas-train-service-has-gone-off-the-rails-even-before-covid-hit-2021-3 (Accessed: 1 May 2024).

Emmer, M. (2015) 'Architecture and mathematics: Soap bubbles and soap films', Architecture and Mathematics from Antiquity to the Future: Volume II: The 1500s to the Future, pp. 449–458.

eTafuleni, A. (2020) 'Enabling Structures: Markets of Warwick Junction. Online. Available at: https://aet.org.za/enabling-structures-markets-of-warwick-junction/ (Accessed: 6 November 2024).

Festus, I.A., Omoboye, I.F. and Andrew, O.B. (2020) 'Urban sprawl: environmental consequence of rapid urban expansion', Malaysian Journal of Social Sciences and Humanities (MJSSH), 5(6), pp. 110–118.

Gauteng Province. (2020) Household Travel Survey Report 2019/20. Online. Available at: https://www.csir.co.za/sites/default/files/Documents/GHTS%20201920%20FINAL_LOW%20RES%20%281%29.pdf

Gauteng Province. (2020) Household Travel Survey Report 2019/20. Online. Available at: https://www.csir.co.za/documents/gauteng-household-travel-survey-201920pdf (Accessed: 2 April 2024).

Harrison, P. and Zack, T. (2012) 'The power of mining: the fall of gold and rise of Johannesburg', Journal of Contemporary African Studies, 30(4), pp. 551–570.

Heidegger, M. 1977. The question concerning technology. Readings in the Philosophy of Technology. 9–24.

Heinzelmann, F. (2018) 'Design method for adaptive daylight systems for buildings covered by large (span) roofs'.

Iyaloo, S., Kootbodien, T., Naicker, N., Kgalamono, S., Wilson, K.S. and Rees, D. (2020) 'Respiratory health in a community living in close proximity to gold mine waste dumps, Johannesburg, South Africa', International Journal of Environmental Research and Public Health, 17(7), p. 2240.

Krieg, O.D. and Menges, A. (2022) Architectural potentials of robotic manufacturing in

timber construction: strategies for interdisciplinary innovation in manufacturing and design = Architektonische Potentiale robotischer Fertigung im Holzbau: Strategien für interdisziplinäre Innovation in Herstellungs- und Entwurfsmethoden. Stuttgart: Institute for Computational Design and Construction, University of Stuttgart (Research reports / Institute for Computational Design and Construction, 11).

La Magna, R. et al. (2013) 'From nature to fabrication: biomimetic design principles for the production of complex spatial structures', International Journal of Space Structures, 28(1), pp. 27–39.

Laciste, K. (2023) Santu Mofokeng, Train Churches. Available at: https://smarthistory.org/santu-mofokeng-train-churches/ (Accessed: 15 September 2024).

Ladybug Tools (no date) LADYBUG TOOLS, food4Rhino. Available at: https://www.food4rhino.com/en/app/ladybug-tools (Accessed: 6 June 2024).

Makinana, A. (2020) 'MPs frustrated at perennial inability of Prasa to put its budget to good use', Online. Available at: https://www.timeslive.co.za/politics/2022-09-07-mps-frustrated-at-perennial-inability-of-prasa-to-put-its-budget-to-good-use/ (Accessed: 1 May 2024).

Mbem, N.H. (2018) Rethinking Railway Histories of the Transvaal: Examining the Relationship between Infrastructure, Modernities and People, 1860s–1960s. University of Pretoria (South Africa).

McLeod, S., Scheurer, J. and Curtis, C. (2017) 'Urban public transport: planning principles and emerging practice', Journal of Planning Literature, 32(3), pp. 223–239.

Menges, A. (2011) 'Simple Systems-Complex Capacities. Integrative Processes of Computational Morphogenesis in Architecture', TECHNE-Journal of Technology for Architecture and Environment, pp. 68–77.

Morapedi, K. and Makhari, M. (2017) 'National transport master plan (NATMAP) 2050', Southern African Transport Conference.

Mtembu, M.S. (2008) 'The architecture of railway stations and transportation nodes, towards the design of a proposed new commuter railway station in Kingspark sports precinct.'

Noh, H.C. (2005) 'Ultimate strength of large scale reinforced concrete thin shell structures', Thin-Walled Structures, 43(9), pp. 1418–1443.

Nwadzule, R. (2023) 'Minister Chikunga opens Leralla to Germiston rail corridor', Online. Available at: https://www.gauteng.gov.za/News/NewsDetails/%7B32fa3f33-a07c-48ab-ae70-524a8afce0de%7D#:~:text=The%20Leralla%2DGermiston%20line%2C%20rebuilt,services%20from%20Germiston%20to%20Johannesburg (Accessed: 14 April 2024).

Oxman, N. (2010) 'Material-based design computation'.

Pirie, G.H. (1992) 'Rolling Segregation into Apartheid: South African Railways, 1948-53',

Journal of Contemporary History, 27(4), pp. 671–693.

PRASA. (2023) 'Minister of Transport, Ms Sindisiwe Chikunga, officially Launch of the Leralla-Germiston line', Online. Available at: https://www.prasa.com/News%2065.html (Accessed: 30 April 2024).

Robert McNeel & Associates (no date) Rhinoceros 3D, www.rhino3d.com. Available at: https://www.rhino3d.com/ (Accessed: 16 May 2024).

Rode, P. (2013) 'Trends and challenges: global urbanisation and urban mobility',

Megacity Mobility Culture: How Cities Move on in a Diverse World, pp. 3–21.

Stats SA. (2023) Land transport statistical release. Online. Available at: https://www.statssa.gov.za/publications/P7162/P7162December2023.pdf (Accessed: 27 April 2024).
Stent, J. (2022) 'These graphs show PRASA's disastrous state', Online. Available at: https://groundup.org.za/article/these-graphs-show-prasas-disastrous-state/ (Accessed: 5 April 2024).

Tang, D. and Watkins, A. (2011) 'Ecologies of gold', Places Journal.

Taylor, J. (2022) 'Back on track: Revitalising SA's rail service', Online. Available at: https://issuu.com/topcomedia/docs/psl_october_22/s/17104715 (Accessed: 5 April 2024).

Taylor, J. (2022) 'Back on track: Revitalising SA's rail service', Online. Available at: https://issuu.com/topcomedia/docs/psl_october_22/s/17104715 (Accessed: 5 April 2024).

Tedeschi, A. and Wirz, F. (2014) AAD - Algorithms-Aided Design: parametric strategies using Grasshopper. First edition. Brienza: Le Penseur publisher.

Venter, I. (2023) 'PRASA sets sights on big recovery in passenger trips by 2030', Online. Available at: https://www.engineeringnews.co.za/print-version/prasa-sets-sights-on-big-recovery-in-passenger-trips-by-2030-2023-12-01 (Accessed: 5 April 2024).

Vincent, J. (2009) 'Biomimetic patterns in architectural design', Architectural Design, 79(6), pp. 74–81.