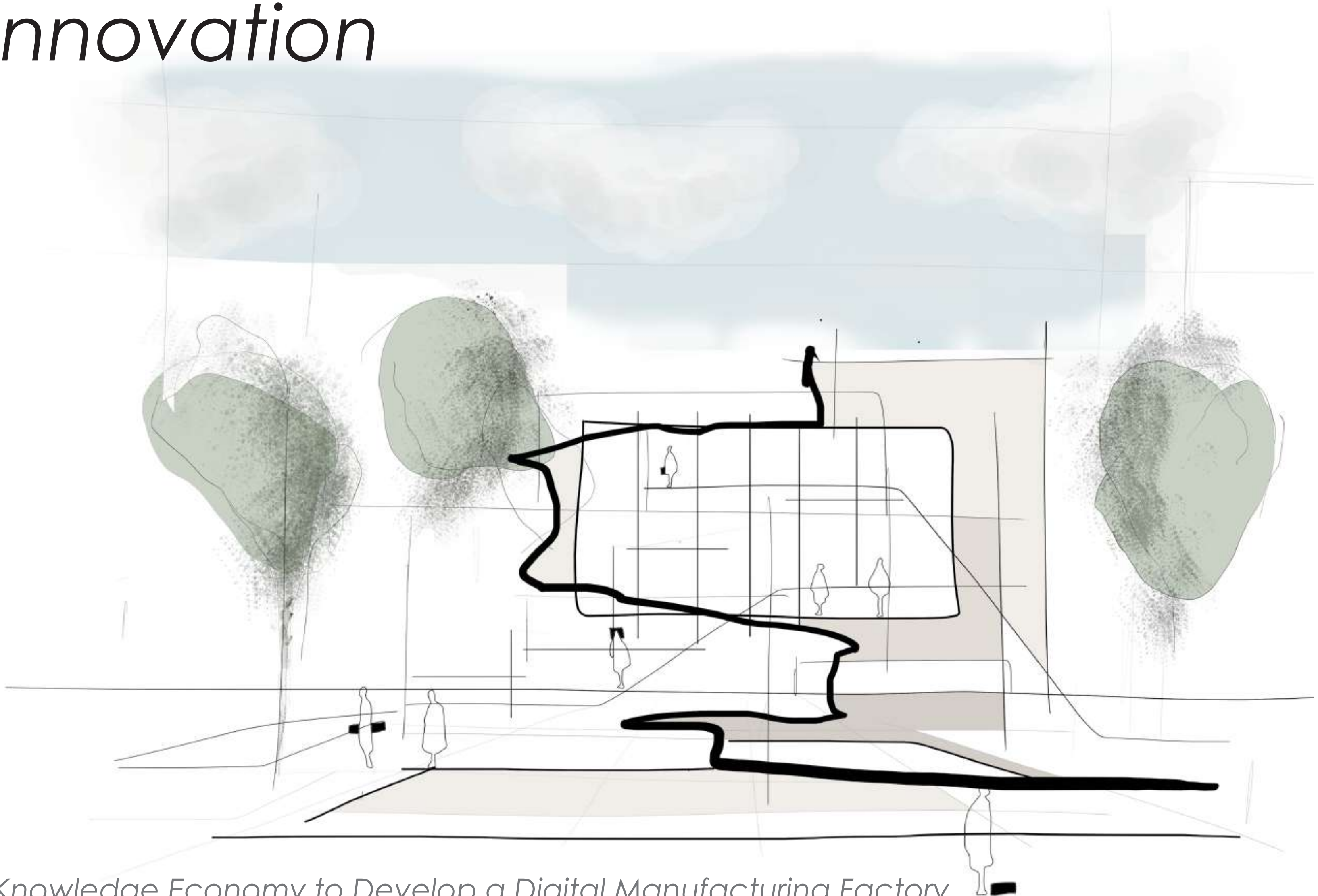
Disruptive Innovation



Harnessing Braamfontein's Knowledge Economy to Develop a Digital Manufacturing Factory.

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Disruptive Innovation:

Harnessing Braamfontein's Knowledge Economy to Develop a Digital Manufacturing Factory.

A research report submitted in partial fulfilment of the Masters of Architecture degree at the University of the Witwatersrand, Johannesburg.

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09-03-2021.

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To my mother , Zvinake Tavuyanago, the rock upon which my foundations are laid. You are an inspiration and I would like to express my gratitude for the love, encouragement and support you offered.

Finally, to my father, Baxter Tavuyanago ,you will always be source of hope, admiration and tenacity. Thank you for instilling the discipline and self belief in me. As this chapter of my education draws to an end, I know you would have been proud.

ABSTRACT
A Digital Manufacturing Factory in Braamfontein

This architectural discourse and design is underpinned by the disruptive potential of digital manufacturing and how such a phenomenon can be harnessed in the local context to develop innovation and creativity. What if this new way of making can short-circuit rapid transformation in local manufacturing by integrating maker, producer and consumer? This theoretical framework argues for the development of a digital manufacturing factory in a dense, urban environment and in proximity to a knowledge based economy and strong research institutes to fully utilise available resources and create a space that develops local ideas, concepts and production.

The chosen research site is an existing VW Retailer and Garage located in Braamfontein, Johannesburg. Dependency on the automobile and combustion engine in the city is unsustainable and is responsible for greenhouse gas emissions, climate change on a global scale and spatial fragmentation at a local scale. As such the fundamental stance taken in this discourse is that of a complete rejection and rebuff of the motor vehicle as a vital component of mobility in the near future. Ride sharing and smart mobility alternatives with an emphasis on pedestrian and commuter movement are the future rendering the use of the current site redundant hence justifying my proposal of a Digital Manufacturing Factory.

RESEARCH QUESTION

Conceptual Framework & Approach

PROBLEM STATEMENT

The research is guided by the following, “How does a Digital Manufacturing Factory become a Catalyst for Innovation, Collaboration and Vibrant Public Space by Harnessing Braamfontein’s Knowledge Economy, Diverse Demographic and Creative Energy?”

This research looks specifically at the current rigid and exclusionary, singular function of the site in relative contrast to the space around it. The argument advanced is that the retail and service of cars is environmentally catastrophic, contextually misplaced and reinforces social polarisation and exclusion. The existing site is functionally obsolete and there is a need to radically transform the purpose and function of the space into a program that is environmentally sustainable, socially sensitive, economically productive and contextually relevant. How can a Digital Manufacturing Factory achieve the afore mentioned need through program, function, tectonics and passive climate design?

KEY SUB-QUESTIONS

(i) How does a digital manufacturing factory proposal foster innovation, exploration and creativity through building function and program?

(ii) How can the rich human resource and skill offered by academic institutions located within the area be used as a tool for creation of a factory that retains intellectual manpower in the region and uplifts the local economy through digital manufacturing?

(iii) Do pedestrians and public transport commuters fit in as the future dominant user of the space? How can the architectural intervention weave and integrate pedestrians, cyclists and public transport into the existing urban landscape to facilitate the free circulation of people?

Design Strategy
Conceptual Framework & Approach

Adaptive Re-Use and Urban Regeneration form the basis of the Architectural Design strategy which has emphasis on sustainability. The full utilisation of Braamfontein's Urban infrastructure is dependent on successfully harnessing its' knowledge economy. The project intends to create a highly productive central point of convergence which is merged with an active public interface between productive and city space. To achieve the afore mentioned, the main design concepts applied to this research are mainly based on Flexibility, Porosity, Collaboration and Sustainability.

SECTION A
Theoratical Underpinnings

SECTION B
Design Exploration

Chapter 1
Literature Review.

SYNOPSIS
This chapter is a synthesis of the main theoretical arguments that informed site selection, program function and urban design methodology of the design proposal. The underlying literature borrows heavily from other fields of study, mainly economics and technology, however an attempt is made to contextualise arguments both architecturally through the use of selected case studies and in the Braamfontein and Johannesburg context. The main purpose of this chapter is to stir insightful thought and conversation on pertinent present day issues and speculate what the implications of current global trends could mean for the local context in the immediate future.

1. DISRUPTIVE INNOVATION
.1 Introduction

The focus of this essay is to consider closely the link between the knowledge economy and innovation and how the two can be synthesised into developing a Digital Manufacturing Factory. Digital Manufacturing has the potential to unlock and discover untapped local creativity and problem solving as it makes the translation of ideas into physical products instantaneous. This process can be catalysed by an efficient and well developed urban ecosystem that links designers, makers, and consumers all in the same vicinity. The essay aims to challenge and question the role of the existing VW retail and garage as a redundant piece of infrastructure, and assess ways in which it can be re-imagined as an intensive production space that is central to collaboration, ingenuity and innovation. The latter form the essence of the architectural design strategy which aims to transform a space that fuels consumerism into one that champions exploration and manufacturing. Primary to this objective, the knowledge economy, smart mobility, agglomeration economy knowledge spill-overs, adaptive reuse and digital manufacturing technology are going to be investigated and explored in detail. The resultant links and connections are going to be tested against the Theory of Disruptive Innovation, which forms the core of the argument, and accordingly applied into the spatial design proposal.

Disuptive Innovation: Main arguement

The main concept of disruptive innovation has dual applicability in the premise of this argument. It refers to the unfolding of a "making" revolution through digital manufacturing and the massive shift from current reliance on the combustion engine (automobile) to a "vehicle-less" future driven mainly by smart mobility alternatives. The main argument of the research is that, digital manufacturing has democratised "making" and the industry is ready for development of new commercially exploitable opportunities, "Disruptive Innovation." This theory was first postulated by Christensen, (1996) and it is based on the rationale that radical transformations driven by technology result in new products and access to markets that displace established entities, "Disruption." Figure 1.1(i) illustrates the notion of disruption which is marked by radical shift and disintergration of an existing system(rigid barrier).

"Disruption" refers to a process where a new entrant (start-up) in the industry with less financial resources is able to successfully challenge and displace established companies with a much larger market share. In most cases, established companies invest on retaining their large market and "usually more demanding customers," resultantly paying less and less attention to sectors of the market that constitute the minority and is in the fringes. Entrants that prove successful start by effectively focusing on those sectors of the market that are overlooked, gaining a foothold by delivering more-suitable functionality frequently and at a lower price. Established companies, "chasing higher profitability in more demanding segments, tend not to respond with speed and flexibility. Entrants then move upmarket, delivering the performance that incumbents' mainstream customers require, while preserving the advantages that drove their early success", (Christensen and Raynor, 2015). When the larger market shifts to embrace the new entrant's (start-up) product in large quantities, it can be argued that disruption has occurred.

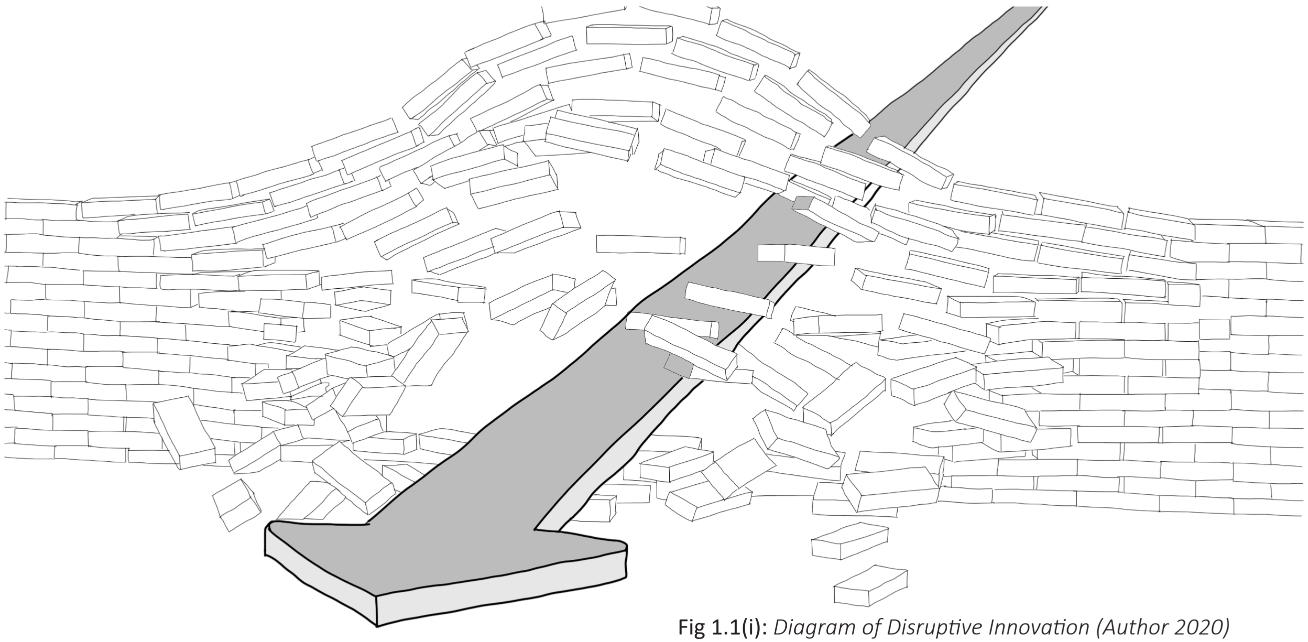


Fig 1.1(i): *Diagram of Disruptive Innovation (Author 2020)*

Disruption in the Braamfontein Context

Disruption put into this discourse context denotes the inception a new form of digital manufacturing located in a dense urban fabric with immediate access to consumer markets. This new form of production which will challenge the location and size of traditional manufacturing factories. This is because production will shift from large warehouses on the periphery of urban centres to small compact innovative clusters in dense urban fabrics. This research also predicts the dissolution of the automobile as a primary facet in the mobility industry as smart mobility alternatives such as ride sharing, communal vehicle ownership and efficient public transportation reduces the need for personal vehicles.

Fig 1.1(ii): *Speculative Future Braamfontein Streetscape (Author 2020)*

Characteristics of Disruption

(i) Low End Market Footholds

Disruptive innovation is a phenomenon that effectively starts in low-end market footholds. "Low-end footholds," exist because established companies focus on servicing the needs of their most profitable and demanding customers", hence paying inadequate attention to low-end consumers,refer to Figure 1.1(c). Ignoring a sector of the market gives opportunity for a disrupter, providing a good enough product, access to this market. Put into the context of Johannesburg, the commuter and pedestrian (lower working class and student population) are largely ignored by major mobility companies such as VW who focus on servicing the middle- and upper-class consumers by producing the automobile. This essay argues that, there is underutilised potential and an untapped market in commuters and pedestrians who offer an opportunity for disruption in the mobility industry in Johannesburg. Resultantly, smart mobility will develop out of the need to access a market that is overlooked and yet rich in potential. The growth of smart mobility alternatives in Johannesburg entails that the current use of site, retail and servicing of personal vehicles, becomes void. This would necessitate the need for a new functional use for the existing site, hence the proposal of a Digital Manufacturing Factory becomes a viable option.

The development of a digital manufacturing factory becomes an alternative use of the existing site as the design proposal will re-use portion of the existing infrastructure as part of a sustainable approach to design. Sustainable design becomes particularly relevant when one looks at the environmental damage caused by the automobile gas emissions. Taking this into consideration, a creative architectural response driven by heightened environmental awareness becomes a necessity and not an alternative.

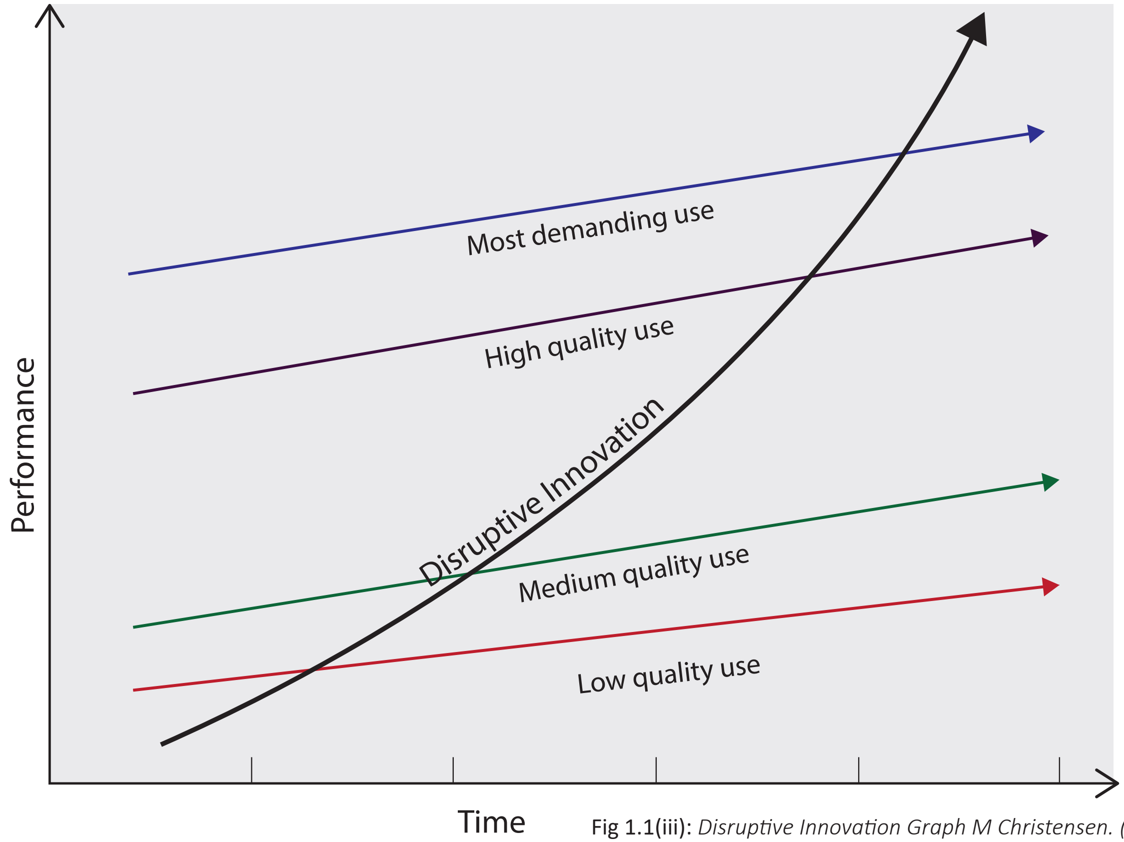


Fig 1.1(iii): *Disruptive Innovation Graph M Christensen. (Redrawn by Author 2020)*

(ii) New Market Footholds

The advent of digital manufacturing can result in the creation of new markets as the versatility of production means a wider range of products are available for consumers. Disruptors create a market where none previously existed and find an effective strategy to turn non-consumers into consumers, (Christensen and Raynor, 2015). Consumers in the digital manufacturing era, will take a more active role in the design and production of their products. This gives rise to a new market of both consumers and producers termed "prosumers", (Berman, 2013). This group will comprise of hobbyists and technology enthusiasts who would require the services of reliable digital manufacturing factory and can work hand in hand with traditional experts to develop ideas and working prototypes.

In relation to smart mobility, by displacing the dominance of the automobile with cheaper, more efficient, green mobility alternatives such as the electric buses, scooters and bicycles, (technology driven mobility) as well as creating walkable city environments, a whole new market of users is opened. In practical terms, if automobile users find a more attractive, convenient and reliable alternative, they could potentially become new customers. At the same time, the smart mobility initiative has the potential to tap into the same existing market of automobile users by taking advantage of the changing models of ownership as users opt for convenience without the hustle of ownership, maintenance or driving, (Lyons, 2016). This trend is noticeable on the growing dependency of ride sharing alternatives such as Uber and Taxify(Bolt).

1.2 SMART MOBILITY
Sustainable Agenda

Movement in the city should leverage technology to improve the quality of service for the commuter and pedestrian while simultaneously offering a viable and sustainable alternative to the automobile. In Braamfontein, Johannesburg Smart Mobility could also enable a refocus on the quality of the public realm and creating desirable and memorable public space. The concept of Smart Mobility applied in the Johannesburg context is about the shift from mobility based on speed and convenience (automobile) to a more comprehensive, multi-modal system. (Litman, 2003).

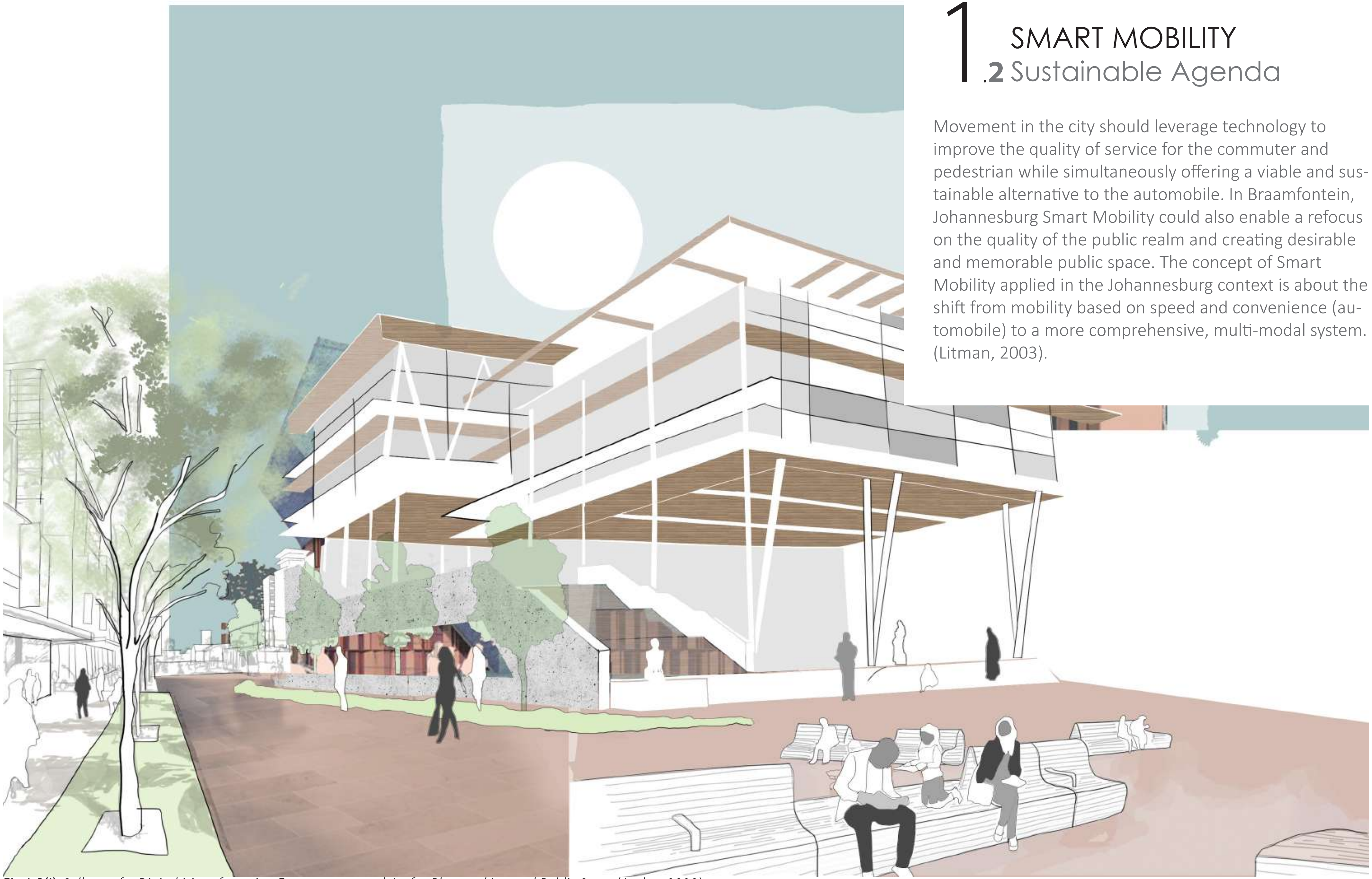


Fig 1.2(i):*Collage of a Digital Manufacturing Factory as a catalyist for Placemaking and Public Space(Author 2020)*

Kamruzzaman et al (2019) postulate that, emissions originating from transport cause about a quarter to one third of greenhouse gas emissions, and that smart mobility should be a vital component of city agendas going forward. Lyons, (2016) is of the same opinion as Kamruzzaman, as he states that the transit of people is by nature problematic as it consumes significant energy and results in greenhouse gas emissions. From the above, it is evident that remedial action needs to be taken in the transport industry to mitigate the damaging effects of greenhouse emissions and this can be done through the adoption of smart mobility.

"Pursuit of smart urban mobility should fundamentally be about improving the fulfillment of access needs," (Halden et al, 2013). This argument is developed further by Lyons, (2016) who emphasises that smart mobility is fundamentally about efficient and affordable connectivity in towns and cities. To elaborate further, Smart mobility prioritises user convenience, sustainability and improved connection of people and places.

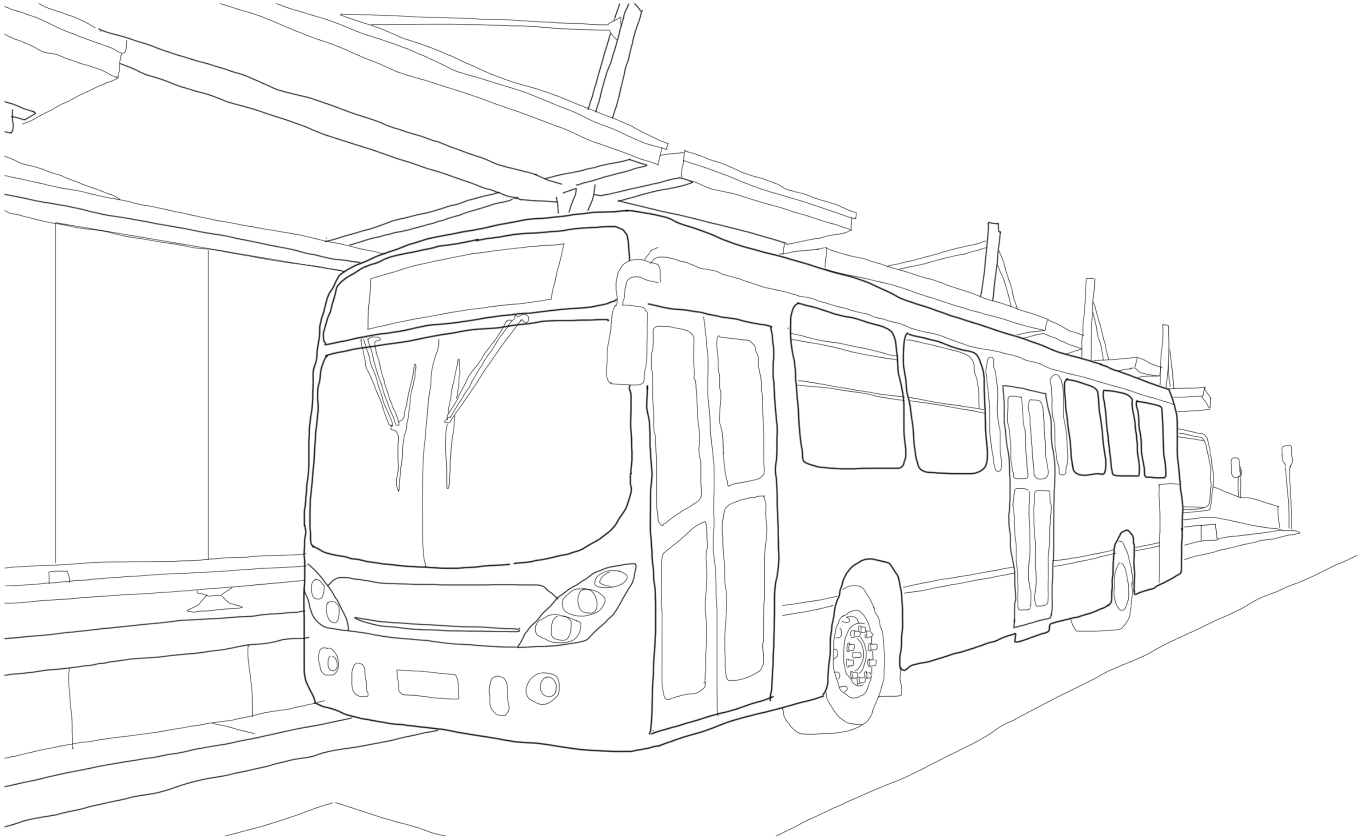


Fig 1.2(ii):*Rea Vaya, Bus Rapid Transport with dedicated lane and bustops to improve convenience (Author 2020)*

It is worth noting at this juncture that the city of Johannesburg historically had a very rich cycling and public transport system that was decimated by the onset of the Group Areas Act of 1950 (Prinsloo et al, 2002). This was compounded by the fact that urban segregation was a policy meant to deliberate fragment the city and divide it along racial and economic lines. As such it can be argued that there is sufficient historical precedent to justify the development of smart mobility in the city of Johannesburg.

Smart Mobility in Braamfontein, is envisioned as integration of the Electric Bus, creation and promotion of a Cycling Culture, Scooters and the optimal utilisation of existing vehicle capacity through ride sharing and on-demand services, (JF Jeekel, 2016). In part some of these ideas have already been implemented with the introduction of Bus Rapid Transport such as Rea Vaya in Braamfontein and Johannesburg, refer to Fig, 1.2(iii).This view is further advanced Kamruzzaman et al, (2019) who argue that smart mobility relies heavily on an efficient public transport network with a minimal environmental impact. The latter will be complimented by a system of safe and continuous cycle lanes and pedestrian walkways, these are anchored by a vibrant public space. Public space design can catalyse efficient thoroughfare and connect rigid divided functional zoning adjacent to transit nodes.

Wilkinson (2012:223) goes on to state that public transport systems can form the basis of a sustainable self-contained neighbourhood. His point of view is expounded by Kelbaugh (2008:40) who argues that traffic-oriented development can be used "to counter physical fragmentation, social polarisation and financial compartmentalisation of a society". Both authors mention the concept of fragmentation as central to their arguments. The term can be used to define the hostility of the Johannesburg vehicular traffic morphology that forms the basis of the city scape. As part of the architectural design strategy the author is going to pay special attention on creating vibrant public spaces, including sidewalks, paths, streetscapes and civic edges and thresholds that encourage lingering, staying and occupation by the passer-by, (Papa and Lauwers, 2015).

CASE STUDY
Copanhagen Denmark

The fundamental ideals of smart mobility such as walkability and integrated multi modal transportation can be particularly observed in Copenhagen, Denmark. To be specific, the city has successfully managed to build bicycle infrastructure and a well-integrated rapid transit and tram systems. Collectively these smart mobility strategies are responsible for reducing automobile use significantly. If the same urban design strategies can be applied to Braamfontein, it would eliminate the need for personal vehicles and thus render the selling and servicing of personal vehicles obsolete and redundant. The impact of adopting smart mobility hence becomes dually functional. It significantly helps improve the urban experience due to less emissions and traffic congestion. Architecturally it opens up the infrastructure responsible for automobile production and maintenance to new functions. It is on the premise of this speculation that this discourse argues for the need to appropriate an existing VW retail and garage and completely overhaul the structure to meet more relevant needs, "digital manufacturing."

Smart mobility in Copenhagen has had a positive impact on the environment reducing fossil-fuel use by over a third and resultantly cutting tons of greenhouse gas emissions annually, (Austin ,2012). Worthy of note is Copenhagen's efficient bicycle network which is part of a system called "green wave" which gives precedent to cyclists over vehicles. The "green wave" consists of thoroughfares designed specifically for cyclists and acts as a highway for bicycles and effectively forms an essential component of the city's smart mobility culture.

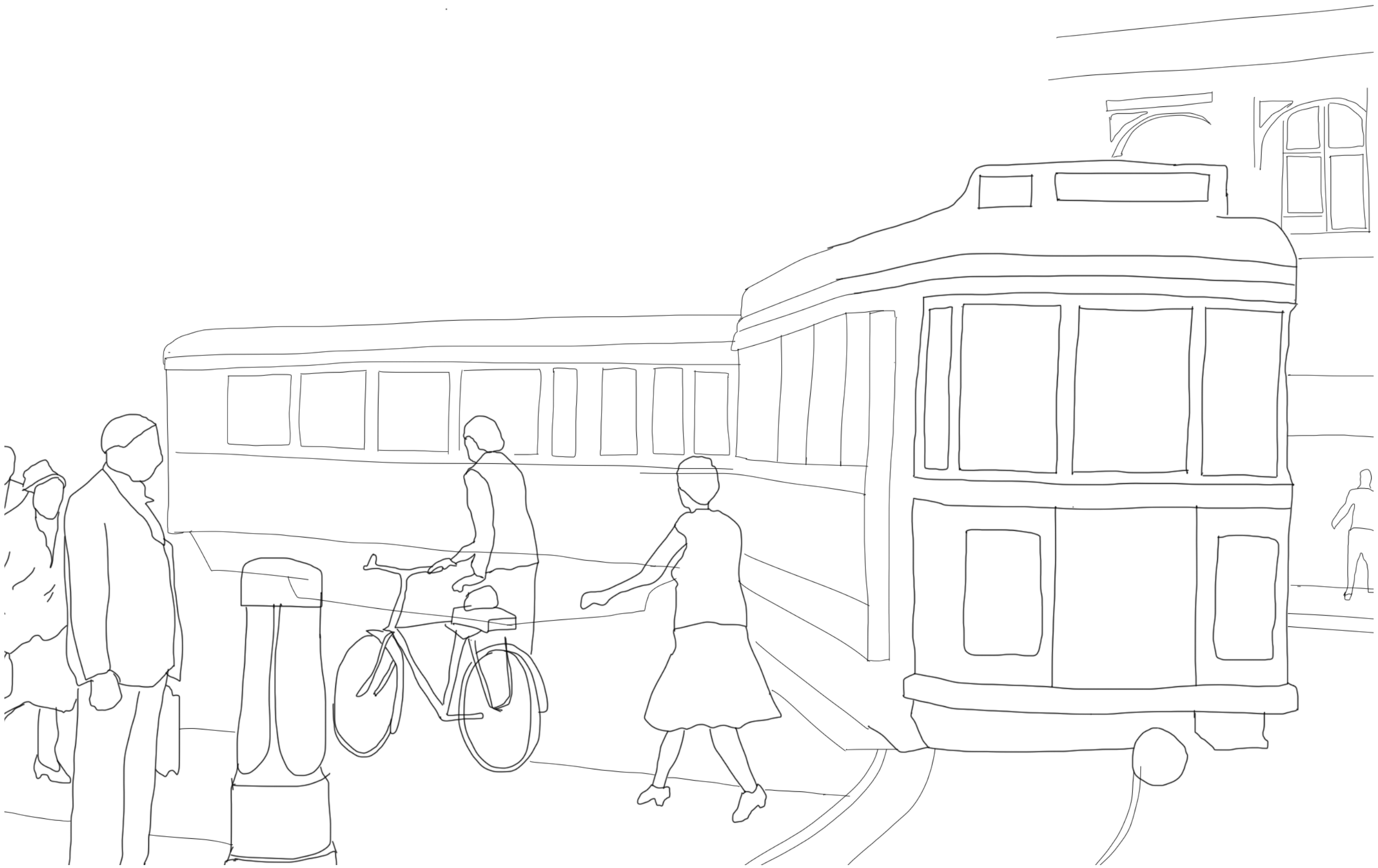


Fig 1.2(iii):*Smart Mobility in Copanhagen. Denmark (Author 2020)*

Fig 1.2(iv):*Cycling Culture in Copanhagen. Denmark (Author 2020)*

The urban city scape of Copenhagen, because of the cycling culture, is aligned with walkable streets designed for human scale and carefully aligned with public space interfaces. This urban design practice is substantiated by Rode, (2014) who concludes that "public space design should be considered a legitimate form of pursuing smart urban mobility. It can create attractive environments for people to work and play in close proximity to one another, reducing the need or desire for motorised mobility." Given the above argument, smart mobility has the potential to reclaim cities from the spatial fragmentation and disintegration that came as a result of urban design driven by "speed and access". Smart mobility principles allow for the reintegration of pedestrians as a primary facet in urban areas.

In summation, technology is the "enabling tool" but insufficient to make 'smart', an urban context without focusing particularly on human needs and their demands as consumers of the service it seeks to create,(Papa and Lauwers, 2015).The smart mobility industry has the ability to disrupt the current hegemony of the automobile which is fast becoming irrelevant and unsustainable. This can be achieved by "ensuring enhanced permeability for pedestrians and cyclists, which in return can enrich the urban realm and influence how people connect in urban environments". At the same time innovation in the sector can create sweeping revolutionary changes that can improve overall commuter and pedestrian welfare in Braamfontein and Johannesburg.

1 KNOWLEDGE ECONOMY
.3 Competitive Advantage

Untapped potential lies in the effective utilisation of intangible assets such as knowledge, skill and innovation. Knowledge is a key resource for competitive advantage, as such it is a tool to champion transformation, create employment and spark economic growth in Braamfontein, Johannesburg. Here the argument follows that a dense concentration of a diverse group of highly skilled people favours frequent contact and thus new ideas and collaboration are likely, (Hospers, 2012). It is this collaboration and creative energy that forms the fundamental argument for the development of a digital manufacturing factory in this discourse.

Hospers, (2012) hypothesizes that "development of knowledge underlies new products, services and processes that constitute the engine of economic progress." To expand on this point of view, knowledge-intensive activities set off a process of "creative destruction" whereby the "existing disappears and something new is born" (Schumpeter,1942). Knowledge is a resource that forms the basis for innovation and has the potential to create an economic system that generates wealth and creates new products. The design proposal aims to use knowledge as a resource that can inspire "Disruptive Innovation" in the manufacturing industry. Innovation flourishes in an environment where knowledge and industry are in spatial proximity and are closely integrated. This phenomenon can be noticed in the area around Cambridge University in the United Kingdom. Clusters of innovation and creativity have formed around an established knowledge and research centre, "Cambridge University", refer to Fig 1.3(iii).

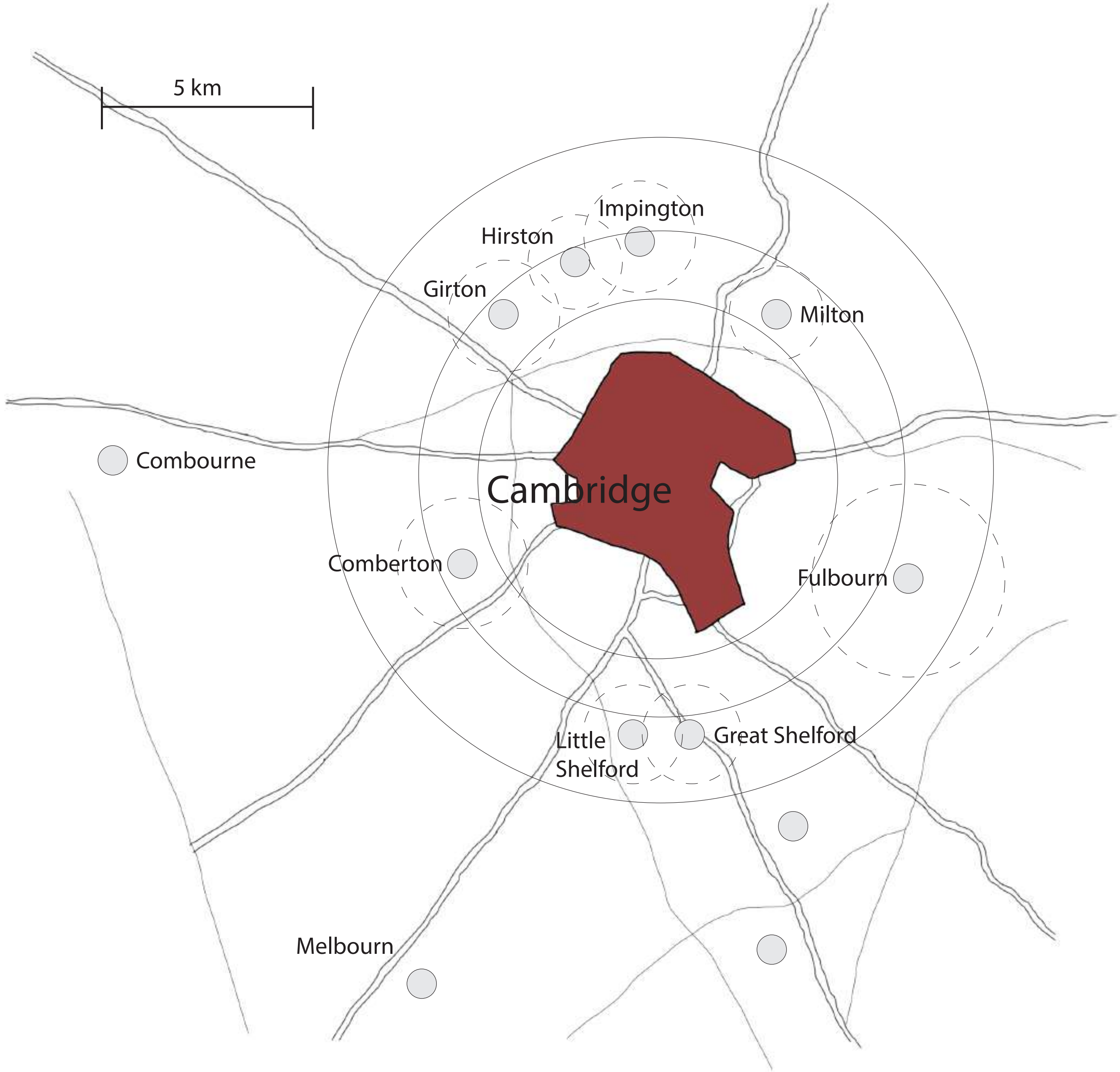


Fig 1.3(i):*Innovation Clusters close to Cambridge University (Author 2020)*

CASE STUDY
Silicon Fen (Cambridge)UK

The concept of localisation and concentration has been put into effect in Cambridge, United Kingdom in a technology research park named "Silicon Fen". This area around Cambridge University has widely been accepted as the "New Silicon Valley", because of its tendency to attract a cluster of technology and innovation driven companies clustering around a research university. The exchange between the university and surrounding incubation hubs has resulted in the successful realisation of experimental research as graduates spin of their ideas hassle free into working prototypes and models. To elaborate, the concentration of highly skilled and powerful minds in one area supported by designers, and freelancers is arguably the best way to spark innovation as proven by the case of "Silicon fen".

A Digital Manufacturing Factory in Braamfontein will act as a catalyst for innovation by providing a space where various creative minds can converge and collaborate. This in turn has the potential to create a sector that employs skilled and semi-skilled youth and tackle the issue of unemployment. Knowledge and expertise combined with the "freedom to make", made possible by digital manufacturing, means that the ability to create is now unlimited and unrestricted. As such, the knowledge economy can be used to champion socio-economic transformation as it enables entrepreneurship and exploration at an unprecedented level.

Fig 1.3(ii): *Cambridge University "Knowledge Generation" (Author 2020)*

Harnessing the knowledge economy for cities means "localisation", concentration of skills in one spatial vicinity (Hospers 2012). This view is supported by Hall (1998) who states that, urban creativity is stimulated by a substantial number of people in a particular location Braamfontein, as a study area suits the afore mentioned description as it is endowed with a highly diverse range of demographics ranging from students, professionals, artisans and academics. The chances of capitalising on the knowledge economy to develop digital manufacturing factory are much higher in such a rich context because of the "increasing returns to scale due to spatial concentration," (Krugman 1995; Porter 1998). Spatial concentration alludes to the density of interaction and not necessarily mere number of people, (Hospers,2012). Braamfontein as a dense urban environment, with a variety of building typologies that attract different users is an example of the afore mentioned creative urban environment as such it is the ideal testing ground for this research. There is higher chance of knowledge and idea exchange that sparks innovation in a context that has a diverse mix of different demographics, backgrounds, professions and academic expertise. Knowledge and technology will be channeled towards developing digital manufacturing and hence the need for a factory to house production and exploration.

Fig 1.3(iii): *Braamfontein's rich diversity in building tyopology (Author 2020)*

The term factory points to an intense productive space that displaces the current use of the site, which is the redundant consumption of outdated technology, (sale and repair of cars). The objective of the design brief becomes about converting a consumer space (VW Retail) into one that is for innovation and creativity through adaptive re-use. To foster new knowledge and creative energy, face-to-face interaction is of vital importance. New ideas and exchange come into being through informal communication and collusions in open undesignated spaces. (Hall ,1998).

Communication and exchange are more likely to happen in a less formal set-up that allows for fluid interaction between individuals from various fields. In this regard the Digital Manufacturing Factory needs to be complimented by vibrant public space that acts as an attractive destination for the diverse Braamfontein demographic. According to Hospers (2012), Creativity flourishes in an unconstrained environment and is a result of coincidence but is incubated and more likely to happen in public space. The design of public space, both on the exterior edges and internally becomes one of the guiding principles in the design proposal.

1. AGGLOMERATION
.4 Knowledge Spill-Overs

Innovative activity should concentrate geographically where there is direct knowledge generating inputs and other industries to maximise the chances of knowledge spill-overs. Geo-spatial proximity between the proposed “Digital Manufacturing Factory” and the “Digital Innovation Lab” (Tshimologong) allows for exchange, knowledge spill overs and local competition which acts as an incentive to engage in innovative conduct, (Jacobs 1969.)

According to Marshall (1920) and Krugman (1991), “there are geographic boundaries to information flows or knowledge spill-overs, particularly tacit knowledge, among firms in an industry.” This argument is further explained by Feldman and Audretsch (1996) who state that innovation and creativity should “concentrate geographically in those industries where the direct knowledge-generating inputs are the greatest and where knowledge spill- overs are the most prevalent.” The above arguments advocate for agglomeration and clustering of industry and knowledge producing entities to maximise interaction and increase the chances of an innovation breakthrough.

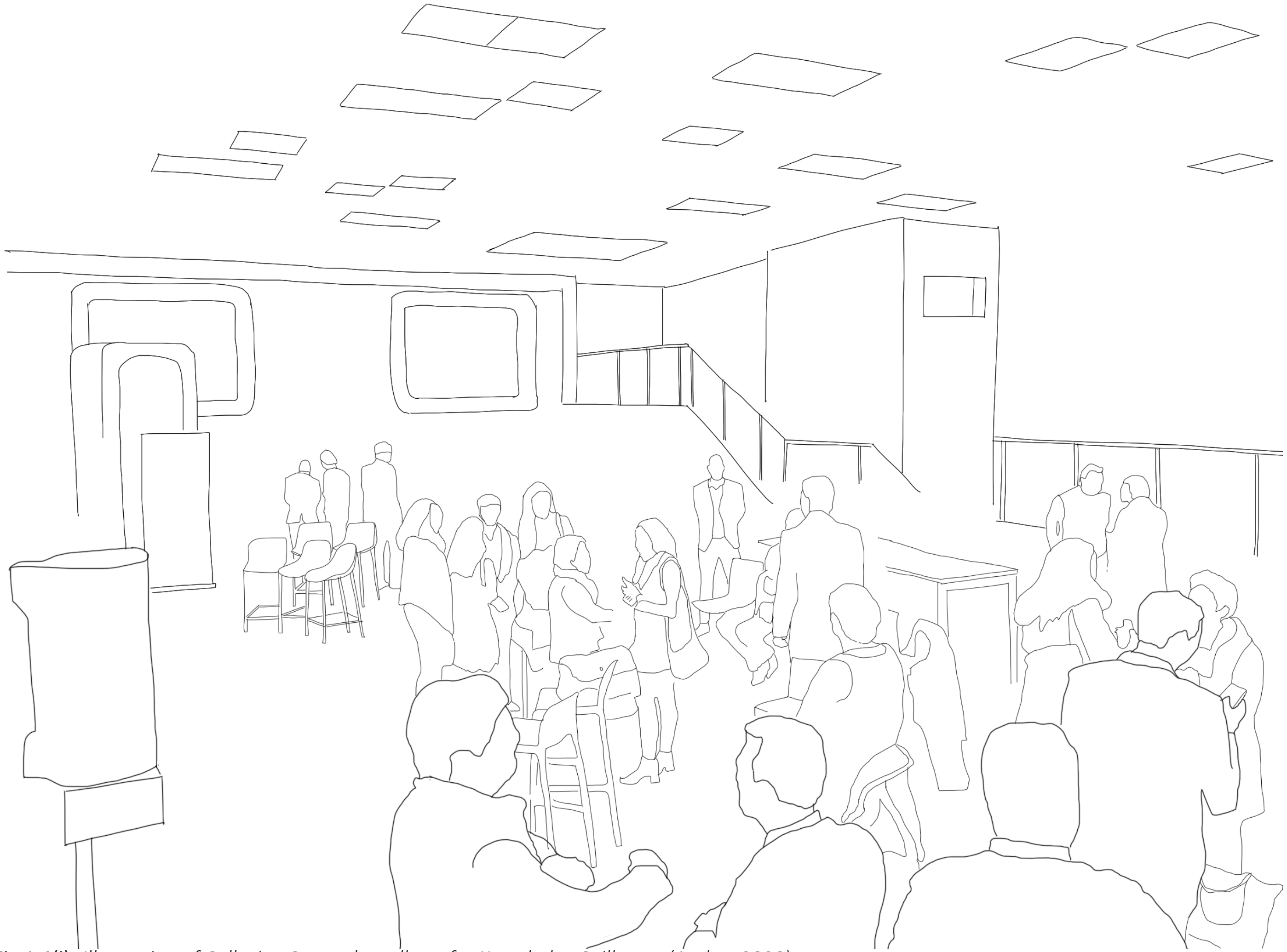


Fig 1.4(i): *Illustration of Collusion Space that allows for Knowledge Spillovers (Author 2020)*

CASE STUDY
Tshimologong (Braamfontein)

Tshimologong is a Wits driven research amalgamation with Microsoft, Huawei and IBM with the focus on software development and digital technology. The building function is experimental and is an extension of the commercial arm of Wits University meant to develop and incubate financially feasible research ideas. At the same time the digital precinct has a specific agenda to empower African students and young professionals who lack access to the technology driven economy. It is against this low skill background in the marginalised parts of the society that a Digital Manufacturing Factory becomes a relevant intervention with the potential to empower the disenfranchised. In particular African, Colored and Indian demographics considered second class citizens during Apartheid suffered from a lack of technology and skill driven initiatives, which the design proposal seeks to redress.

Fig 1.4(ii): *Knowledge Sharing inside Tshimologong (Author 2020)*

The Tshimologong Precinct draws strongly from the principles of clustering and knowledge spill overs as it houses several technology companies under a conglomeration of buildings and spaces. It can be argued that by having Microsoft, Samsung and Huawei in proximity to each other, there is high chances of idea exchange and competition which fuels innovation. Central to achieving the above, the spatial layout and design of the precinct is the use of public and collaborative spaces. Special attention and detail is given by the designers of the space to allow for flexibility and adaptability of the architecture. Architecture is more than a rigid shell, it should also be interactive.

"A key feature of successful innovation clusters is the high level of embeddedness of local firms in a very thick network of knowledge sharing, which is supported by close social interactions and by institutions building trust and encouraging informal relations among actors", (Breschi and Malerba 2014).

It can be argued that the above applies to Tshimologong as it is en-grained in Braamfontein where there is the well established University of the Witwatersrand and significant commercial enterprises coupled with residential. This rich combination is conducive for the cross interaction that favours innovation.

SITE SELECTION CRITERIA

The choice of "site" is particularly relevant as it is positioned near the University of the Witwatersrand University (Wits) as well as the Tshimologong Digital Innovation Precinct. Accordingly, positioning a Digital Manufacturing Factory next to Tshimologong (Digital Technology Innovation) lowers the cost of knowledge transmission. Spatial proximity means that workers are more likely to exchange ideas and information, especially if their chances of coincidental encounters are increased by the careful manipulation and design of collusion space, (Breschi and Malerba 2014).

This argument is in direct contrast to Krugman and others, who postulate that "knowledge flows are either unmeasurable or are spatially unbounded in a world increasingly linked by information highways." Krugman's argument has been strongly opposed and questioned by (Feldman and Audretsch, 1996) who claim that "the production of innovations presents a strong tendency to cluster in locations where key knowledge inputs are available." It can hence be concluded that ,"knowledge tends to spill over locally and takes time to diffuse across geographic distance." (Jaffe,1993). From the above, it can be deduced that geographic location has a direct effect on the intensity of knowledge spill-over and exchange. As such, to maximise innovation potential, the Digital Manufacturing Factory will be positioned next to an existing digital innovation hub, Tshimologong and Wits University, thereby creating and strengthening a knowledge cluster.

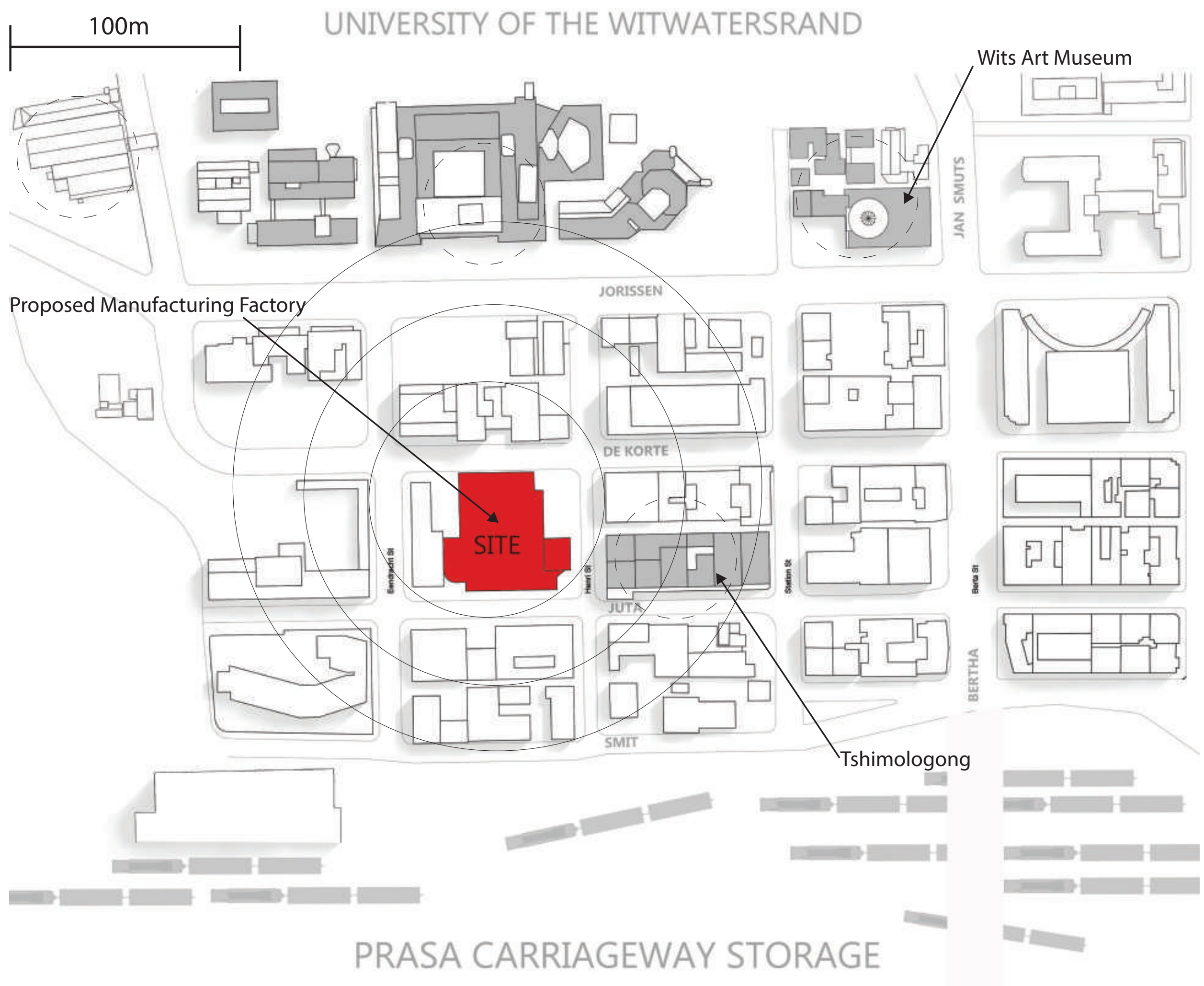


Fig 1.4(iii): *Chosen Site and its Relationship to Knowledge Generation and Industry(Author 2020)*

It is therefore argued that the proposed "Factory" can siphon the existing knowledge and skill found in Braamfontein and the resources of an established research institution, Wits University. By interweaving the two together the program of the design proposal maximises on creativity and innovation potential. This methodology is endorsed by Breschi and Malerba (2014) who claim that "geographical proximity often overlaps and combines with institutional, organizational and technical proximity in fostering processes of collective learning."

They go on to postulate that expert manpower is a vital precondition in creating the basis for entrepreneurship and taking advantage of market opportunities not yet exploited. In summation, the digital manufacturing Industry in Johannesburg is relatively new and unexplored with enormous innovation and business potential. As such it is key that the knowledge and skill in Braamfontein be harnessed in fully exploring the fore mentioned industry.

1.5 ADAPTIVE REUSE
Sustainable Agenda

How best can architecture make use of the untapped potential of existing buildings through appropriation and remodeling to meet new functional needs? Re-use of existing infrastructure is sustainable as it entails reigniting life (social and economic) in the Inner City of Johannesburg as well as reducing the carbon footprint of new-construction and complete demolition. In the context of this Research in Braamfontein, Adaptive Reuse is envisioned as radical transformation in the use and configuring of an existing VW retail space. It is envisioned as a place where innovation and production of new technology takes place.

Fig 1.5(i): *Collage of Proposed Adaptive Reuse of Existing Site (Author 2020)*

Global warming as a consequent of climate change is one of the most significant predicaments facing humanity, and every other life on this Earth, (Stern, 2006). However, the built environment, as one of the major culprits responsible for the climate crisis, is in a unique privileged position to implement impactful change by making better use of existing infrastructure, (Langston, 2008). As a result of this newfound sense of responsibility, sustainability has become essential in the practice of architecture and the built environment. Sustainable design has a heightened sense of the impact of buildings on the environment as such advocates for highly adaptable buildings with a low carbon impact, (Bullen 2007).

Within the broader argument of adaptability, "existing buildings that are obsolete or rapidly approaching disuse and potential demolition are a 'mine' of raw materials for new projects; a concept described by Chusid (1993) as 'urban ore'." This concept of recycling raw materials from a disused building is the most economic and responsible way of achieving sustainability. This approach favours the preservation of basic structural elements and the re-purposing and reinvention of existing spaces as opposed to complete demolition and deconstruction. This approach is called "adaptive reuse" and forms the basis this architectural discourse' design strategy.

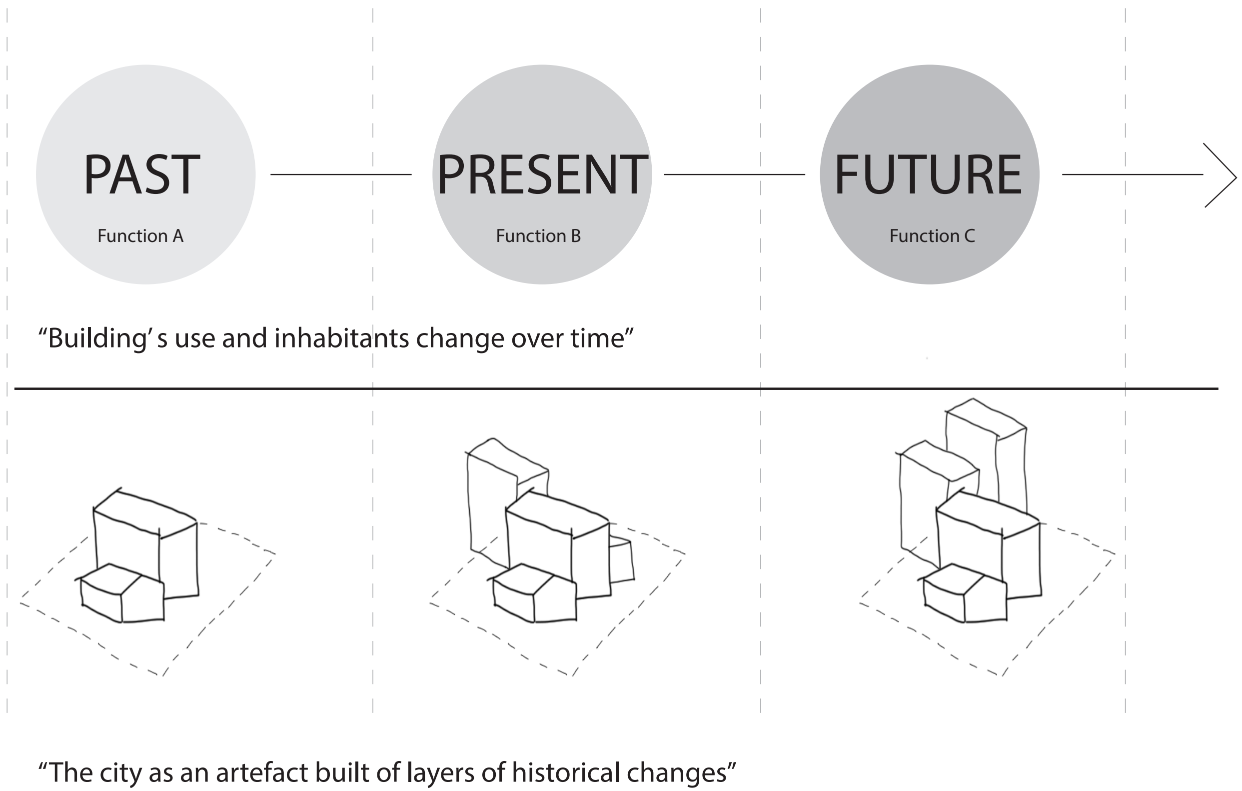


Fig 1.5(ii): *Diagram illustrating the concept of Adaptive Reuse (Author 2020)*

Adaptive re-use is the process of re-purposing the function of obsolete buildings for new program through building transformation and conversion (Eyuce and Eyuce, 2010). Adaptation describes "rehabilitation, renovation or restoration works that do not necessarily involve changes of use," (Holyoake and Watt, 2002). Adaptation entails the extension of building lifespan by re-purposing its program and function. This methodology is environmentally sensitive and sustainable as it significantly lowers new construction material required and the energy consumed through logistics and transportation, (Douglas, 2002).

The adaptation process is mostly based on the use of the existing and this is not only limited to architectural elements, it also refers to existing infrastructure such as roads, water, sewer, and electricity. So, the term adaptive reuse also labeled "re-architecture" implies much more than the reinvention and re-imagining of the architecture structurally, functionally, and spatially.

CASE STUDY
Zeitz Museum (Capetown)

Adaptive Reuse is a design strategy implemented in the design of Zietz Contemporary Art Museum, Capetown. The project done by Heatherwick Studio re-imagines a disused grain silo structure into a program that is civic and a cultural relic such as an art museum. The gigantic concrete tubes that were used for storage suddenly became irrelevant overtime, and it is in this context, that the idea of re-purposing the structure was born. What stands out in this project is how the functionality of the original structure went through a complete overhaul changing from mere storage, to a space that is cultural and inhabited. At the same time it is also interesting to note how the designers preserved the structural integrity of the grain silos, in the process preserving a historical artefact but adapting it modern functional use and program.

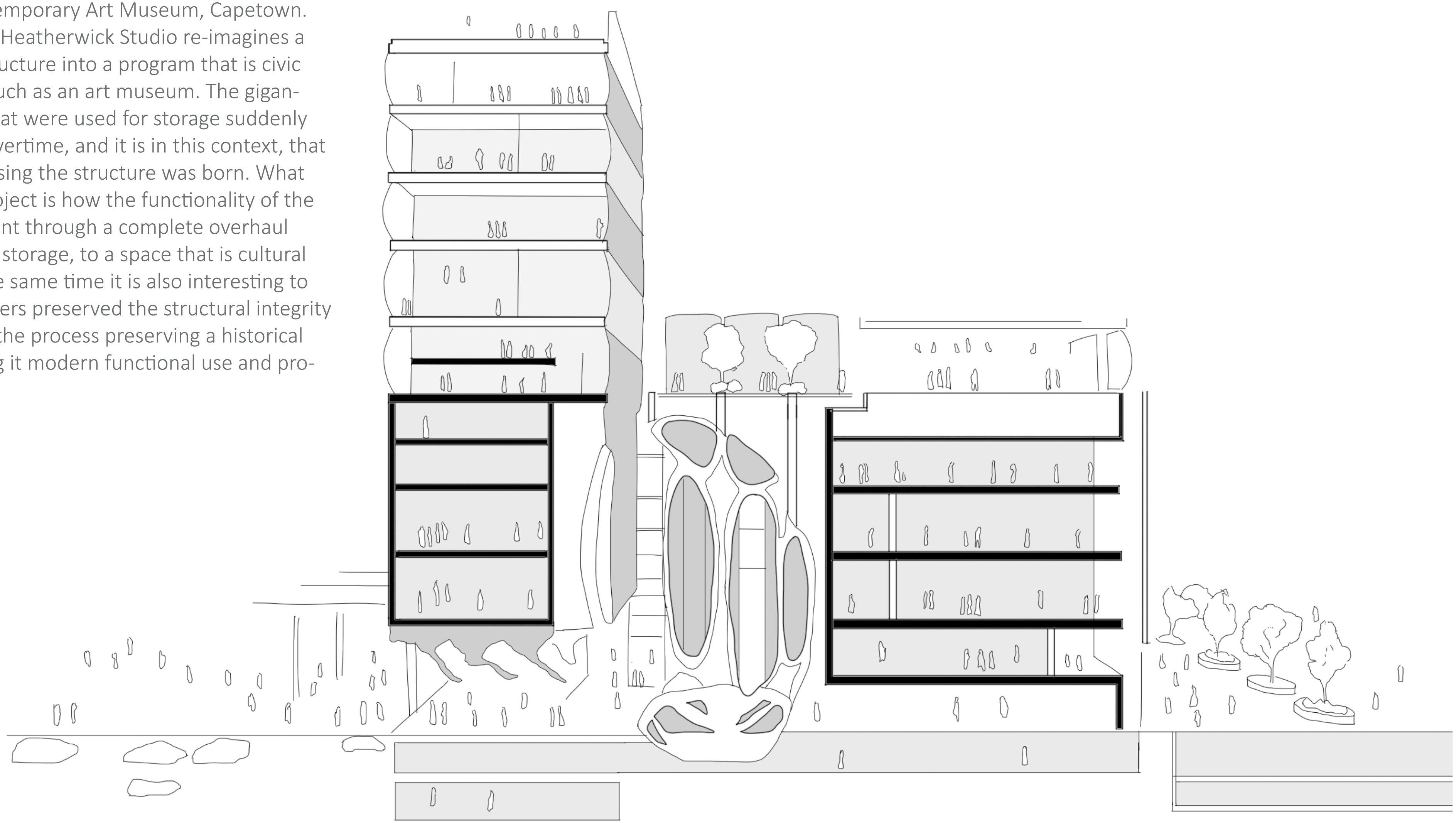


Fig 1.5(iii): *Zeitz Museum by Heatherwick Studio Capetown (Diagram Redrawn by Author 2020)*

In the case of the existing building on site, the VW retail and garage offers a solid structure with wide open spaces that can be appropriated and changed in terms of its function, which is increasingly becoming obsolete. This becomes highly relevant when one considers that the function of an existing building ought to be redundant first and the replacement program has to be financially feasible before adaptive reuse can be applied. “Building obsolescence is the natural outcome of the changing modes of production and consumption triggered primarily by the consequences of technological transformation and change. (Eyuce and Eyuce, 2010). The combustion engine automobile is increasingly coming under scrutiny for its high carbon footprint and environmental destruction. It has been argued that it is an outdated and uneconomic industry that is functionally obsolete hence the justification to appropriate the VW Retailer and garage. The VW outlet will be remodeled as a Digital Manufacturing Factory with emphasis on production and output, this will constitute a process of disassembly and reassembly, “Disruptive Innovation”.

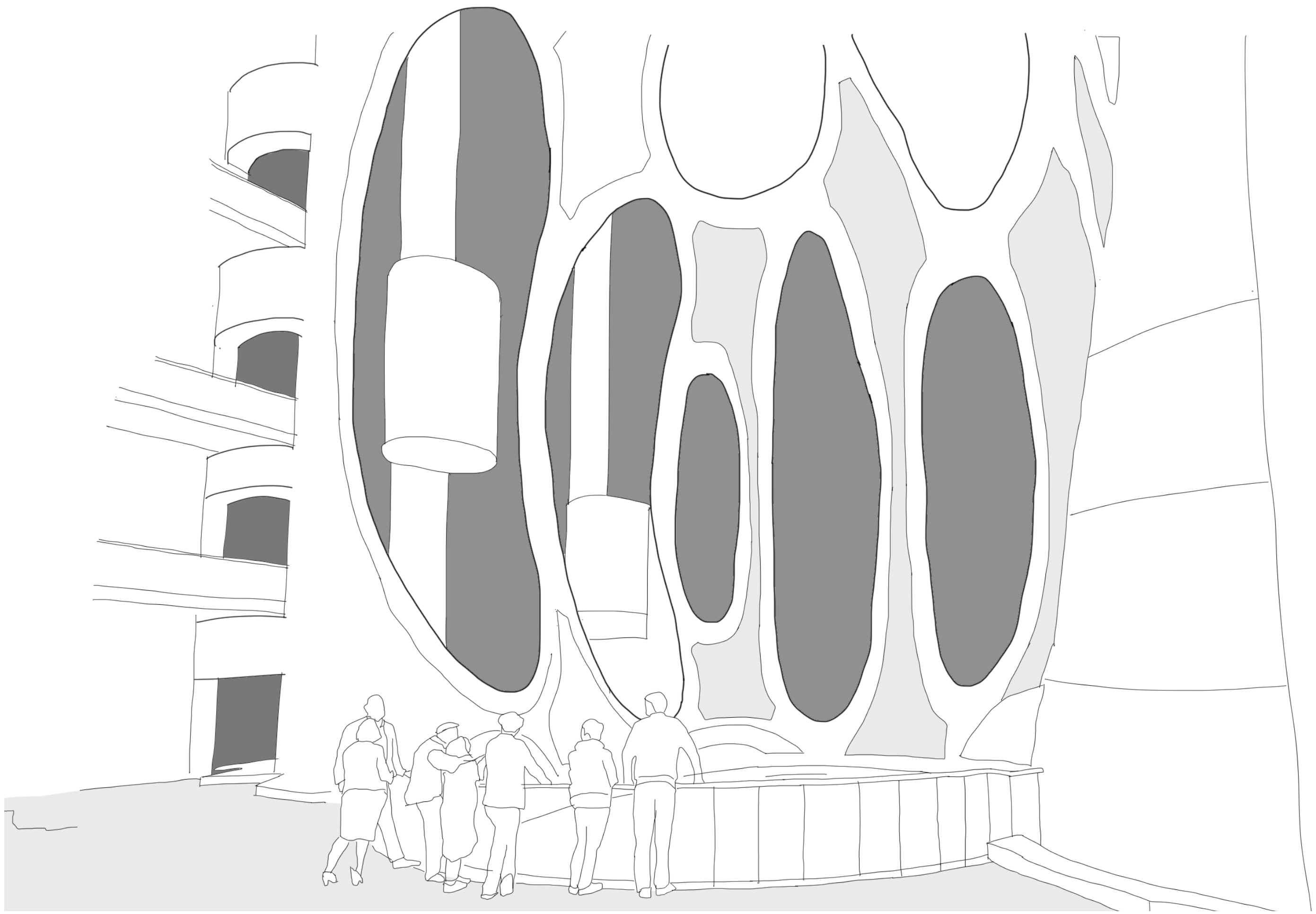


Fig 1.5(iv): *Interior Perspective of Zeitz Museum by Heatherwick Studio, Capetown (Author 2020)*

End of Chapter

Chapter 2
Digital Manufacturing.

The Unfolding of a "Making Revolution"

SYNOPSIS

In this chapter the focus shifts from a broad understanding of relevant literature to the very specific phenomenon of digital manufacturing which underpins the building typology, function and construction technology. The arguments put forth are largely based on predicted trends and future gazing, resultantly the author's voice is more prominent and assertive to ensure the backdrop of the design proposal is clearly communicated. The chapter is meant to create the conceptual basis for an architectural intervention as such the conversation is continuously redirected towards that end.

2.1 BACKGROUND
History of Manufacturing

The first industrial revolution of the late 18th century arguably gave birth to the modern factory as we have come to know it today. The era marked the first major shift from handcraft production, which was slow and small scale, to the present day highly mechanised production system. Standardisation and mass production hence came to characterise manufacturing in the period post the first industrial revolution, (Marsden 2014). This mode of production was driven by high output and limited variation to maximise profitability in a process called "economies of scale." This basic economic principle was later to govern the development of future factories which leveraged technology and innovation to increase production fueling consumerism and the growth of capitalism.

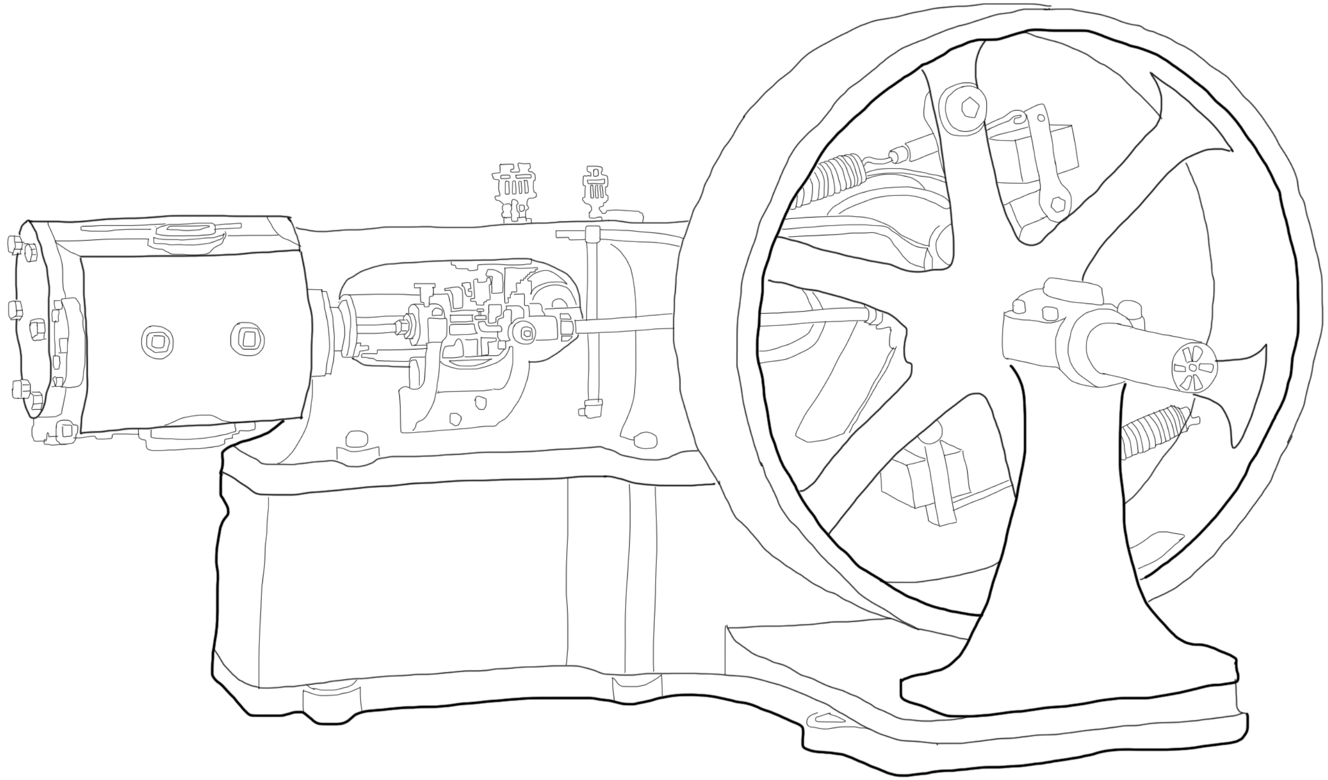


Fig 2.1(i): *Early Industrial Steam Engine (Author 2020)*

The first industrial machinery driven by steam power was clunky and bulky. This meant that huge volumes of space were required to house these machines. This consequently gave birth to the huge warehouses that are closely associated with the factory typology today. At the same time very few individuals could afford the massive "sunk costs"or start up capital, required to own a factory (means of production), hence the gap between the rich and the poor was exasperated as those with access to capital further enriched themselves at the expense of the working class.

It can be argued that the first industrial revolution brought about social polarisation which resulted in a class system, exploitation of labour and commodifying of human capital. These issues are largely responsible for the negative connotations associated with the "factory" typology. However, is it possible that a new way of making "digital manufacturing" can radically undo some of the damage done by the early stages of manufacturing? This chapter looks at ways in which "disruptive innovation" in the manufacturing industry can remedy the destructive and divisive nature of traditional manufacturing.

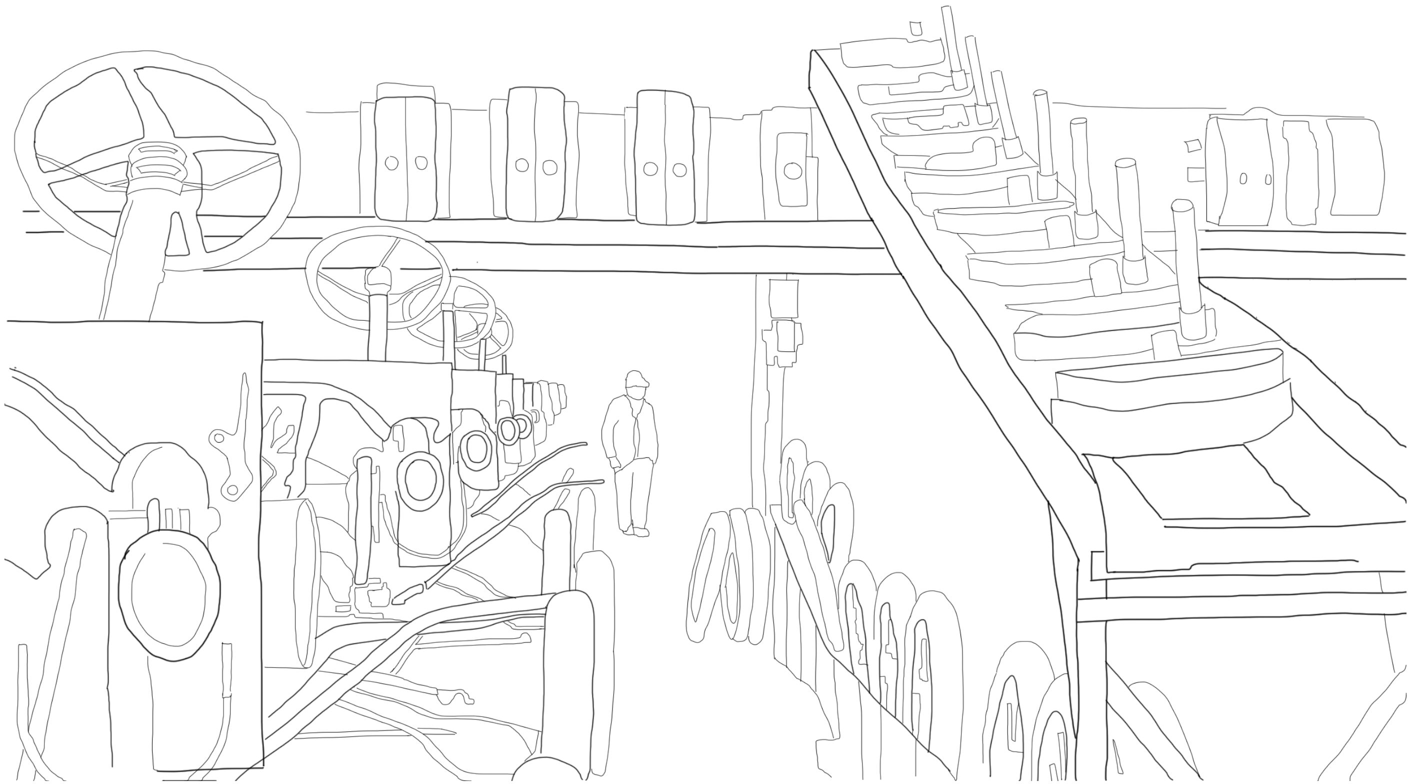


Fig 2.1(ii): *The Assembly Line "Fordism" (Author 2020)*

The second most significant event in the history of manufacturing was the invention of the "assembly line" by Henry Ford. It is a good example of one of the many iterations meant to improve the "economies of scale" production model. The assembly line came to be characterised by heavily mechanised equipment and machinery giving rise to the medium to large warehouse typology associated today with industrial buildings. To enable, mass production, the fixed costs and investments that were put into these manufacturing processes were high and resulted in large organisations and corporations. A new form of concentrated capitalism was born as multinational companies with large market shares and industry monopolies thrived.

However, in 1952, researchers from Massachusetts Institute of Technology where, for the first time, able to use a computer program to directly print a physical object marking the dawn of digital manufacturing era, (Marsden 2014). The development of this technology was relatively slow and was not widely adopted in industry mainly because of its slow output speed and the inefficiency of early computers. The afore mentioned disadvantages have since been dissolved with the continuous improvement of computers hence digital manufacturing technology has presently evolved to an extent where it can be adopted for industrial use.

The term digital manufacturing refers to a new way of production that merges digital and physical model space. It mainly uses additive manufacturing or 3D printing which more or less refer to the same process. Using this process, objects are produced through the creation of additive layers from a printer or robotic arm. The printer reads a digital model which it interprets as a physical manifestation that is a built-up form, (Simson 2013).

MANUFACTURING IN AFRICA.

African technology and manufacturing is a topic that has not been extensively researched and written about. It remains a grey area which requires further investigation and understanding. This discourse argues that African manufacturing technology predating colonialism, was not only ahead of its time, but also responsible for great innovations celebrated to this day.

Precolonial Africa was engaged in mining and simple manufacturing that stretched from the production of cloth and pottery in the Munhumutapa Empire in 15th century to the production of elegant granite bricks in the construction of the majestic Great Zimbabwe. Green (2016) argues that Africans were not passive victims of harsh environmental conditions, they particularly were very good adaptors and displayed high proficiency in experimentation and building technology. This is evidenced by the sophisticated construction technology used at Great Zimbabwe in the 12th century. The construction involved the extraction, molding and precise dry walling of granite rock under very specific artificial conditions to achieve the splendor and rigidity that is the structure today.

From the above it can be argued that technology, manufacturing and innovation are systems that are inherently African. As such it is of vital importance to siphon the dormant creative and innovative potential of Southern Africa by investing in a Digital Manufacturing Factory.

2.2 Democratisation of Making

Additive manufacturing has the potential to liberalise the restrictive, exclusive nature of traditional manufacturing from a creativity point of view. This revolutionary way of manufacturing blurs the very rigid line between design and manufacturing as it enables direct translation of complex digital data into physical objects, (Jiang et al), refer to Fig 2.2(i). Consequently, the designer is afforded a new form of freedom to make and sculpt, without the constraints of traditional manufacturing. Traditional manufacturing techniques are highly restrictive as they require simple designs and parts that optimise high volume output. "For a long time, design was viewed as a process of circumnavigating the constraints imposed by the traditional manufacturing process", (Simson 2013).

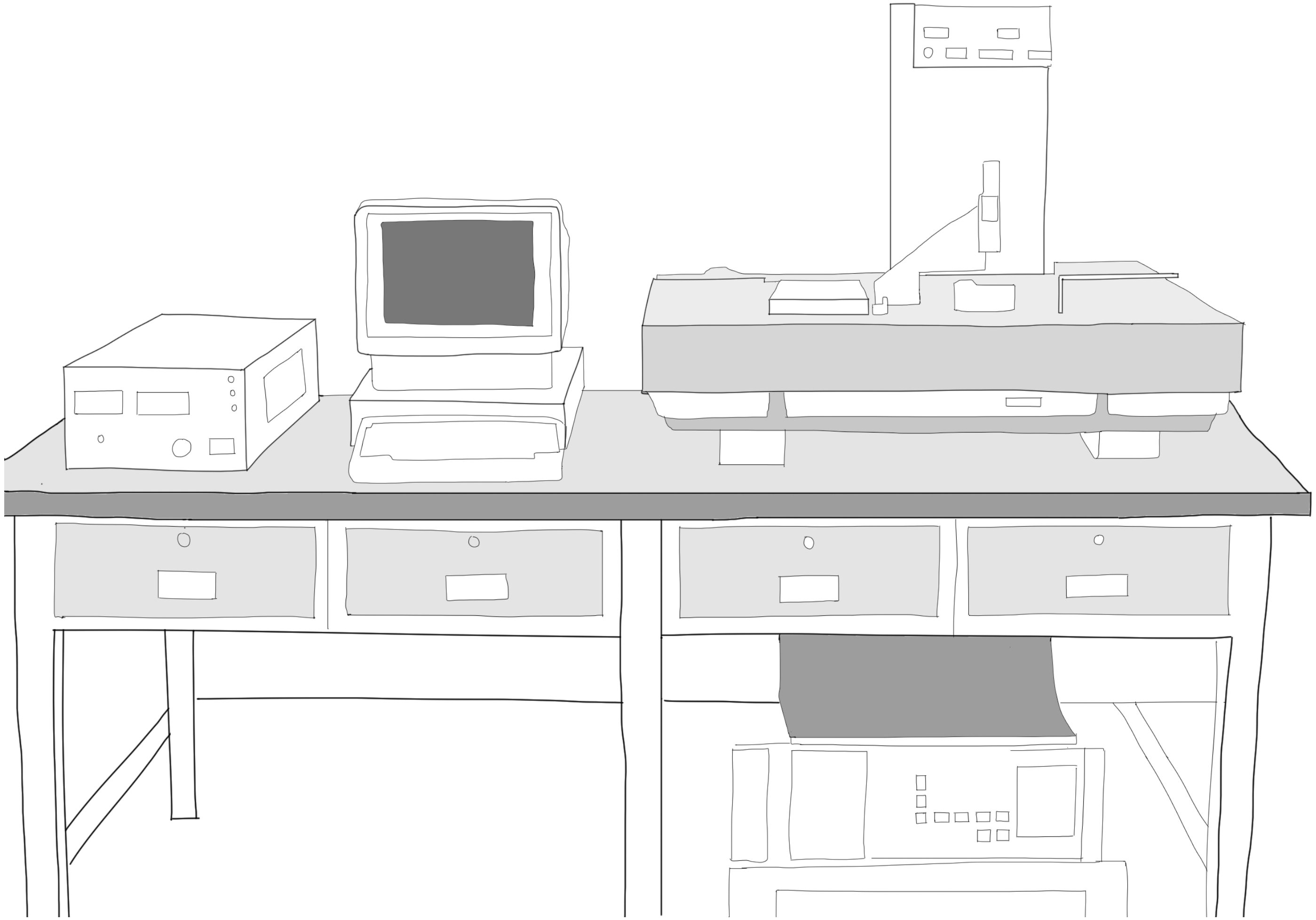


Fig 2.2(i): *Early Iteration of Digital Manufacturing (Fordism) (Author 2020)*

Digital manufacturing entails that the scope of design has suddenly become unconfined and a product of one's imagination. This newly found freedom can disrupt and revolutionise the manufacturing industry as it significantly expands the realm of creation and realisation. Whereas traditionally "design" was limited by available manufacturing technology the advent of 3d printing entails that the inverse is now possible "manufacturing for design as opposed to design for manufacturing." (Beam 2013).

More importantly, the integration of design and manufacturing means that a completely different field is being conceived were design has been extended beyond traditional experts to a wider range of competent individuals. As a result, access to idea realisation through making is no longer restricted and exclusive. This means that established entities in manufacturing face competition from entrepreneur designers who can produce and make through 3D printing. Hence it can be argued that digital manufacturing lowers market entry barriers.

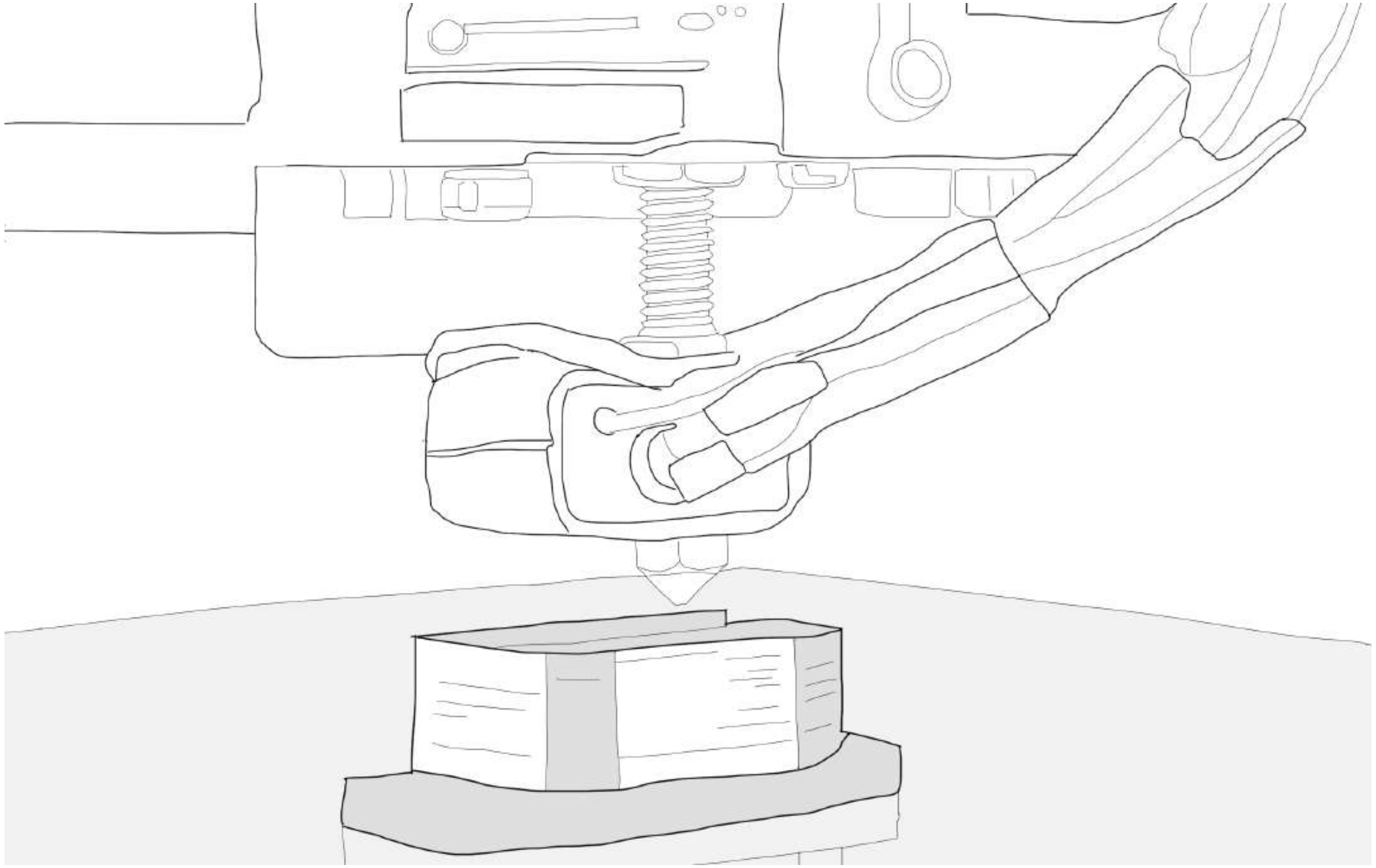


Fig 2.2(ii): *Addittive Manufacturing, Robotic Arm Adding Layers to form a Physical Object . (Author 2020)*

By simplifying entry into the manufacturing industry, the disruptive technology becomes a tool for economic and social emancipation as entrepreneurs and start-ups can challenge established entities. This is largely because digital manufacturing uses additive printing which does not require tools or molds thus eliminating sunk costs before production starts (Gibson et al). This acts as an incentive for disruptors, innovators, and start-ups because the initial capital required to start production is significantly less than in traditional manufacturing. At the same time flexibility in making, means variations and customisation can be explored without additional costs.

The manufacturing industry has hence been opened in a way that liberates makers, creators, and innovators to experiment and produce. Put into context, it is this "freedom" to make and produce that can be beneficial to an emerging economy such as South Africa. More specifically, there is need to leverage and exploit the potential of digital manufacturing and provide platforms and spaces where experimentation and making are encouraged and nurtured. The author envisions in Braamfontein, Johannesburg a space where digital and virtual imagination become realised as physical products, and ideas are fostered into working solutions for local issues and problems. Such a space would help in tackling rising unemployment by offering opportunities to creatives and innovators to develop their concepts into businesses.

Given the low skill base of South Africa in general, the development of a complex digital manufacturing factory seems some what contradictory to the available resources and skill available locally. Yet it is this same sophistication that can be used as an empowermet tool. The rationale here follows that if unemployed, impoverished and disadvantaged youth can be equipped with the latest manufacturing technology, not only is it emancipating but also a potential avenue for economic growth and development for the local production industry.

This discourse argues that "architectural design" in particular building program and function is a tool that can be used to lead and champion a manufacturing revolution. Here the arguement is based on the ideology that a "new form of making" requires a new set of networks and connection which also necessitate a new building typology. On that basis, the term "Factory"is not limited to simply the process of production, but more importantly conceptualisation and experimentation. Hence going foward the focus of the study becomes a matter of using architecture to test out what makes a "creative, collaborative and making space?"

If the process of making has been democratised, as argued in the preceding paragraphs, is it possible to imagine the same for the function and programing of a building? Can spaces be highly adaptable be able to accomodate ever changing functional needs? These are some of the questions raised in the theoratical section of this discourse and through rigorous experimentation answered in the design exploration section.

2.3 Economics of Manufacturing Disrupted

Traditional complexities in the manufacturing industry are going to be eradicated as the competitive advantage of “economies of scale” are replaced by “economies of scope” brought about by the diversity and flexibility of digital manufacturing. To elaborate, “economies of scale” leverage the advantages of mass production, fixed costs, and market share/monopoly to produce homogeneous products in large volumes such that the “unit cost” is significantly low (Siemsen et al). This traditional method of manufacturing suffocates competition and new entrance, as it is capital intensive and heavily reliant on global chain logistics and distribution networks. Conversely, additive manufacturing is highly versatile and flourishes under environments where customisation and complexity are required at no extra cost. “There are no penalties associated with a higher degree of product variety”, (Lolt et al, 2011). Hence there is a marked shift from scale driven manufacturing to one of “scope” driven by variety and customisation which fully utilises the flexibility of additive manufacturing, refer to Fig 2.3(i).

Because of the disruptive nature of additive manufacturing, production economics is predicted to shift from dependence on global supply chain systems to more localised customer requirements and networks. Developing countries and emerging economies can utilise the versatility and range of additive manufacturing to develop their own industries that focus on producing local goods to service local markets. The localisation of production helps develop and nurture local skills and knowledge, which results in economic empowerment of the local population. In that vein, Braamfontein, Johannesburg would be an ideal location for the development of a digital manufacturing factory as it is densely populated with a skillful and knowledgeable diverse demographic. Proximity to Wits University and other colleges also means that there are research facilities and expertise to help realise the full potential of digital manufacturing in Johannesburg.

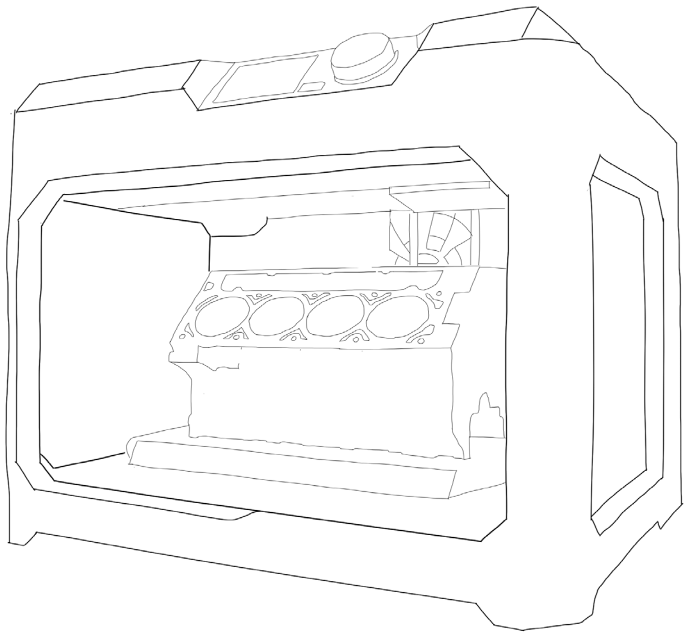


Fig 2.3(i): *Modern 3D Printer, Capable of Producing a Variety of Products. (Author 2020)*

The emergence of e-commerce coupled with the unique ability of additive manufacturing to customise products could potentially result in a seamless relationship between manufacturer and consumer, where profitability is realised by serving small market segments. The versatility of additive manufacturing means consumers can use e-commerce platforms to customise and order products online that can be delivered straight from the manufacturer. Subsequently, this eliminates the need for manufacturers to produce for speculative markets and thus reduce both over production and under production. In other words, manufacturers can “operate with little or no unsold finished goods inventory”, (Berman ,2015). This newfound relationship between industry and consumers will mean that consumers will be able to communicate directly with designers and be involved in the co-creation process. As a result of the above there will be a potential shift in consumer behavior and demands as they also become part of the “making” process. Globalisation will hence be reversed and replaced by localisation and production will be pulled by customers as opposed to being pushed into a market, (Siemsen, 2010).

2.4 Competitive Dynamics of Digital Manufacturing

The additive manufacturing process is highly versatile, experimental, and inexpensive in comparison to traditional manufacturing. These attributes make the former competitive and more viable as an alternative to production as it marks a departure from the linear methodology that prohibited mistakes and was expensive to set up. The versatility and flexibility of additive manufacturing is made possible by the close correlation between digital models and physical fabrication. To elaborate, additive manufacturing means a product is made from the bottom up by a process of continuously adding layers in a 3d printer which reads a Computer Aided Design (CAD) model which exists in digital format. 3D printers use CAD to "create and build paths that produce a physical model through consolidation of materials with an energy source", (Chan et al, 2015.) This way of "making" does not have the constraints of an expensive mold, cast or assembly thereby making it possible to make a variety of products with one manufacturing machine. Variety makes it possible to be more experimental, inquisitive, and innovative, especially if the exploration comes at no extra cost as is the case with additive manufacturing.

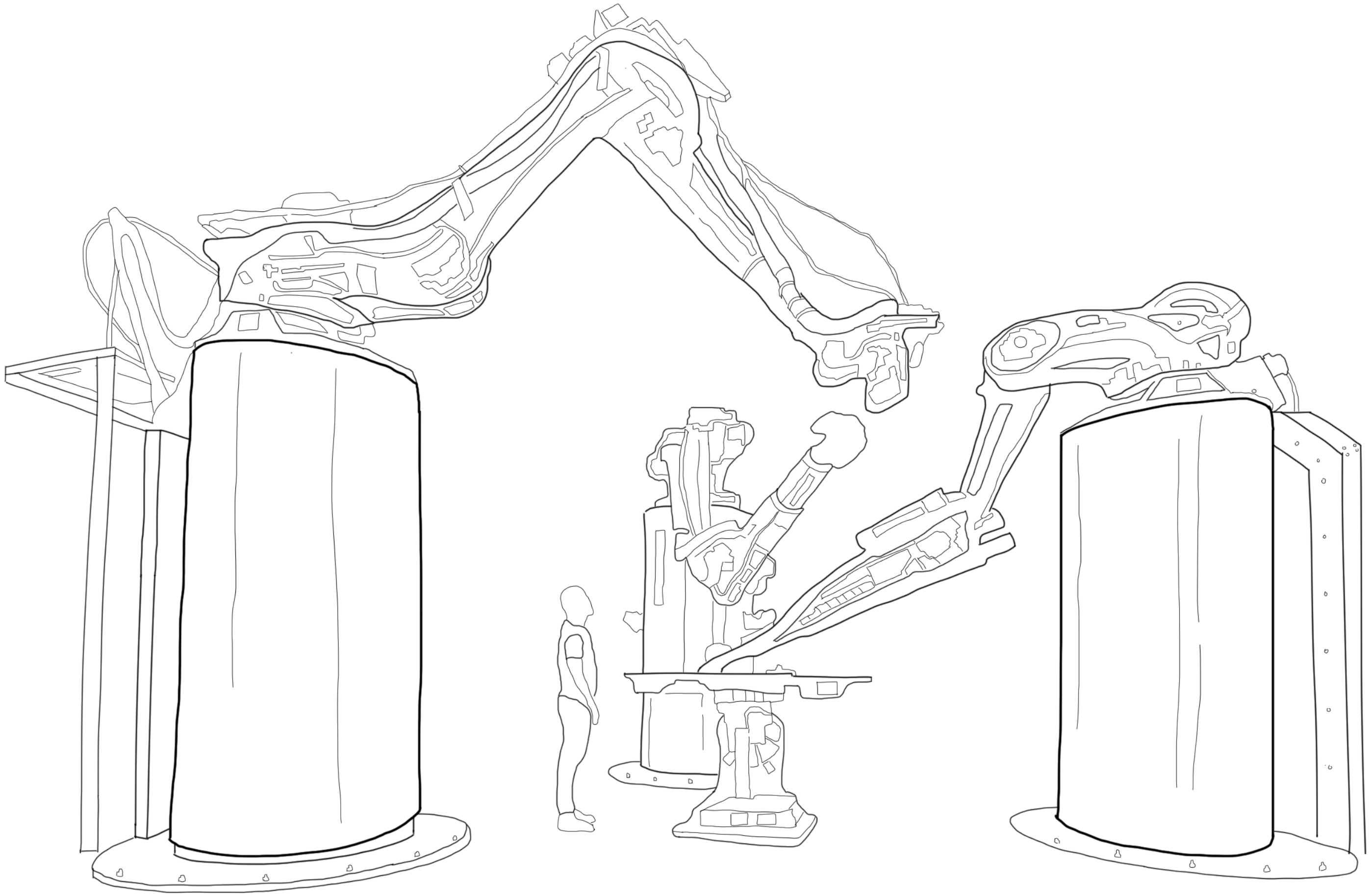


Fig 2.4(i): *Industrial Scale Digital Manufacturing. (Author 2020)*

The new process is precise and efficient because of the seamless communication between software and hardware. This revolutionary method of "making" is disruptive and "enables flexible production of customized products without cost penalties in manufacturing, (Weller et al). Consequently, flexible production means that manufacturers can service a wider market range. In other words, additive manufacturing makes the shift from mass production to specific customisation and individualisation not only possible, but perhaps also desirable.

Fig 2.4(i) illustrates digital manufacturing on an industrial scale. Although the technology is still under development, its advantages are too great to ignore its massive potential. More importantly the notion that, "anything that is conceivable and digitally modeled can be physically realised" will have such a profound effect on the way traditional manufacturing fundamentally works with all its limitations, highlighted earlier. Is it possible to imagine buildings made in this way going forward?

The flexibility of additive manufacturing also exists in terms of location and scale of the new form of manufacturing. As a result of localised production, interaction between designers, consumers and production becomes much stronger hence leading to a need for spatial proximity. The factory of the near future is a manifestation of collaboration, interaction, and networking as such it is ingrained in the urban ecosystem and is therefore located in a dense environment with access to consumers, creatives, and researchers as major spatial location informants.

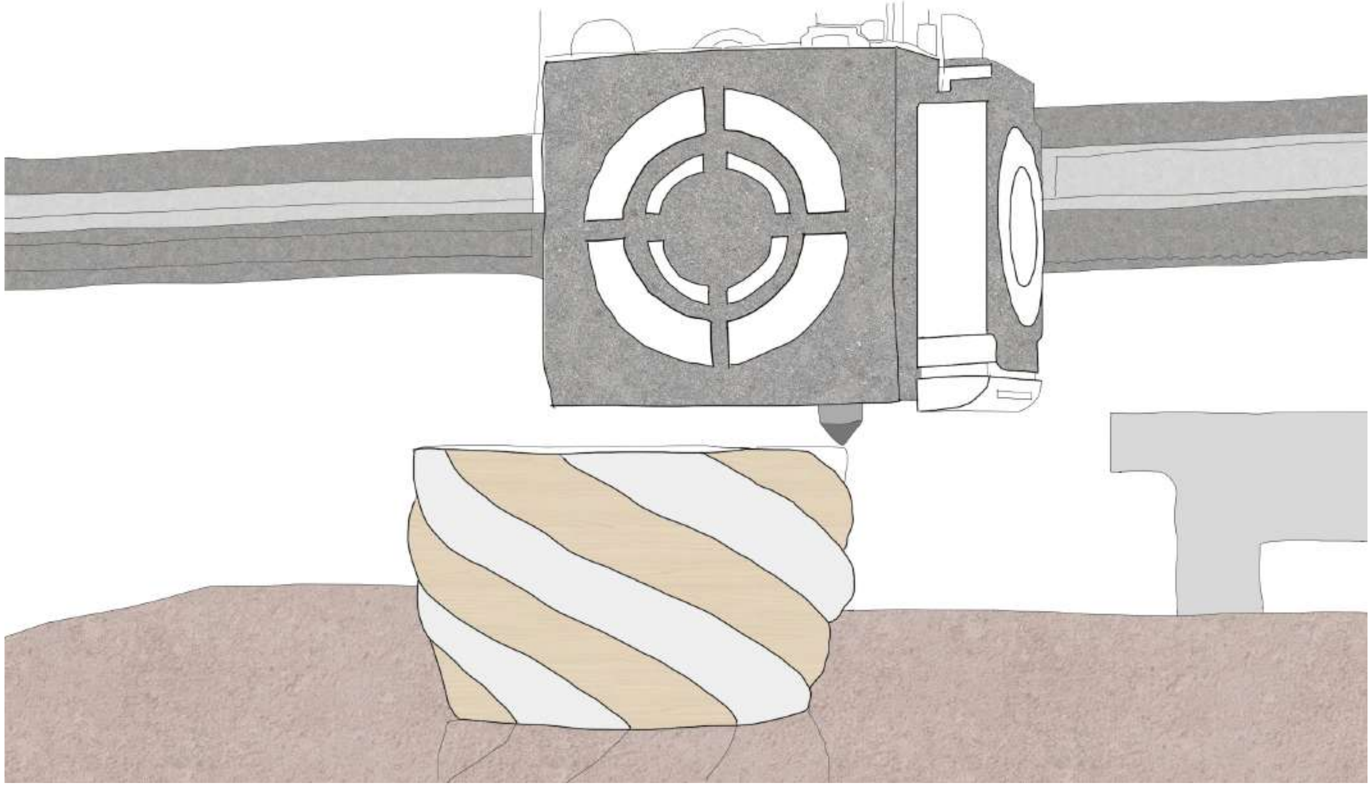


Fig 2.4(ii): *Addittive Manufacturing Flexibility, "Physical Model Built through layering." (Author 2020)*

Manufacturing no longer needs to happen in large warehouses on the periphery of cities. It is no longer a heavy industrial process with clunky mechanical machinery that is inefficient and devastating to the environment. Rather, through the advent of digital manufacturing, it is moving towards a clinical and efficient intricate craft, that is driven by precision and customisation because of CAD and 3D printing. The inherent nature of this new form of manufacturing means that it is technology and innovation driven as such it is dependent on a developed knowledge economy base. Such ideal conditions can be found in a dense, educational urban environment such as Braamfontein, Johannesburg. This assumption is based on the fact the University of Witswatersrand, Rosebank College, Damlein Collage and others are located in Braamfontein.

The author argues that the flexibility of digital manufacturing should be replicated in the architectural design methodology. The architecture should be driven by disruptive innovation in construction technology and the design of collaborative and innovative space. The tectonics of the "design proposal" should reflect a shift from the heavy and rigid concrete construction to the more precise and efficient assembly of timber and prefabricated polymers. More importantly the process of manufacturing is going through an evolutionary stage that draws from experience and methods of making. It is thus necessary from an architectural discourse point of view for the design proposal to reuse elements of the existing structure on site. "Adaptive reuse" will hence form part of the design strategy on the chosen site.

2.5 Methods of Digital Manufacturing

Digital manufacturing is a broad term that defines a relatively new, experimental way of making characterised by the extensive use of computers in the production process. At the present moment the field is broad and continues to expand at an exponential rate. On that basis this discourse will specifically focus on two methods of digital manufacturing, which are Additive Manufacturing (3D Printing) and Laser Cutting. The working assumption here is that , the afore mentioned are currently the most common methods of digital manufacturing technology.

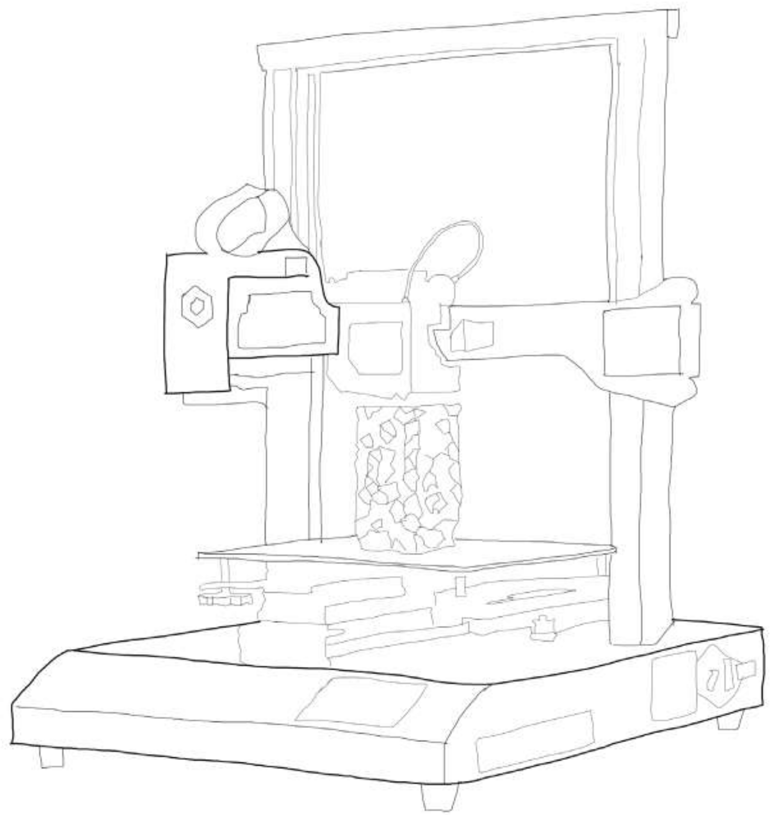


Fig 2.5(i): *Fused Deposition Modeling Machine, "Additive Manufacturing." (Author 2020)*

ADDITIVE MANUFACTURING.

Also known as 3D Printing (Additive Manufacturing) involves the translation of a (CAD) file into a physical object. The resultant object, (model) is built through a process of layering. It is this notion of building from the bottom up where the name additive manufacturing originates from. It is representative of the making process. Information is relayed from designer to computer and lastly to printer, where the idea is realised. 3D printing can be defined as the computer controlled precision layering of basic elements that bond together as they are laid down, (Berman et al, 2012.). As a manufacturing process additive manufacturing it is revolutionary. It is challenging the traditional notion of making as an industry that is exclusive and dependent on complex logistic networks.

FUSED DEPOSITION MODELING (FDM).

Fused deposition modeling can be defined as a 3D printing technology that works by extruding a thermoplastic polymer through a heated nozzle which gets deposited on, in building stages. Refer to Fig 2.5(i). It is a typical example of additive manufacturing. The process involves a plastic filament which is fed to the nozzle where the material is liquified and forms. Rapid prototyping forms the core of the 3D printing FDM process and it is one of the clear advantages of the technology because it enables experimentation and quick conceptualisation. It is from this subsequent trial and error of multiple iterations that feasible products are born. Using this form of manufacturing process productivity is achieved by grinding a product from concept to market quickly and inexpensively.

STEREOLITHOGRAPHY. (SLA)

As the oldest additive manufacturing (AM) technology, stereo-lithography (SLA) was first developed by Dr. Hideo Kodama in 1981. He saw it as a fast and low-cost method of reconstructing models in 3D space as an alternative to holographic techniques. The first commercially available SLA printer was patented in 1986 by Charles W. Hull, who founded 3D Systems Inc. Their aim was to facilitate rapid prototyping of plastic parts. With the development of a variety of processes, SLA has far surpassed its initial applications in modeling and prototyping and can be utilized to manufacture highly complex and individually designed geometries. It uses light usually from ultraviolet laser to turn chemical resins like liquid plastics into solids.

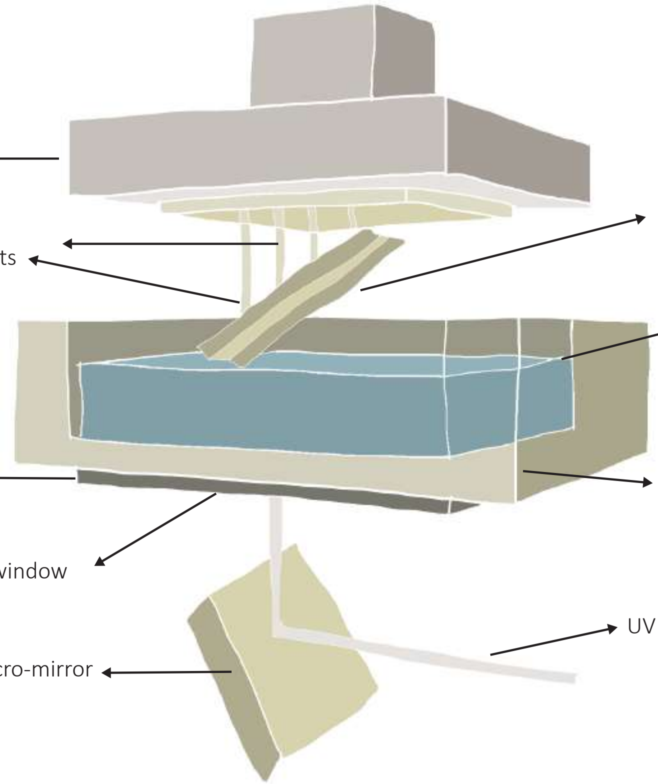


Fig 2.5(ii): *Diagram illustrating how Stereo-lithography works (Author 2020)*

HOW DOES IT WORK?

SLA uses light as the main element in the production of digital prototypes. It works by concentrating rays of ultra-violet (UV) laser reflections on photo-polymer resins. The particular role of the UV laser is extrapolate a predetermined, (CAD) design by detailing the form and shape on to the surface of the photo-polymer. Photo-polymers are the desired material because of their particular sensitivity to light in general. Using this method, the prototype is built via layering in a bottom up, methodology. The prototype (digital model), built using this method is built in parts with the laser beam tracing out the pattern of the surface of the liquid resin. Exposure to the UV laser areas then enhances the solidification of the pattern traced on the resin when the process is repeated continuously.

The whole structure is held together by supports to make it structurally sound and solid enough to adequately handle the task required of it. Refer to Fig 2.5(ii). The diagram illustrates the relationship between the main components of SLA, which are UV light, Resin and Image Projection Window. The UV light is the one that projects CAD designs onto the Image Projection Window which then traces out the form of the model from the resin. The process is done layer after layer until a solid prototype emerges from the resin.

Laser Cutting

Laser cutting is a production process that creates and amplifies a narrow intense beam of coherent, highly energised light resultantly creating cuts that are a direct interpretation of a computer model, (Bodaniya 2018). It is a thermal based non-contact process capable of cutting complex contours on materials with a high degree of precision and accuracy. This definition is expounded on by Madiac et al (2012) who states that "laser cutting is a thermal, non contact automated manufacturing process." The precision and speed at which designs can be translated into form makes laser cutting a highly effective method of digital manufacturing. According to Senthilkumer 2016, *"Laser cutting involves a process of heating, melting and evaporation of material in a small well defined area."*

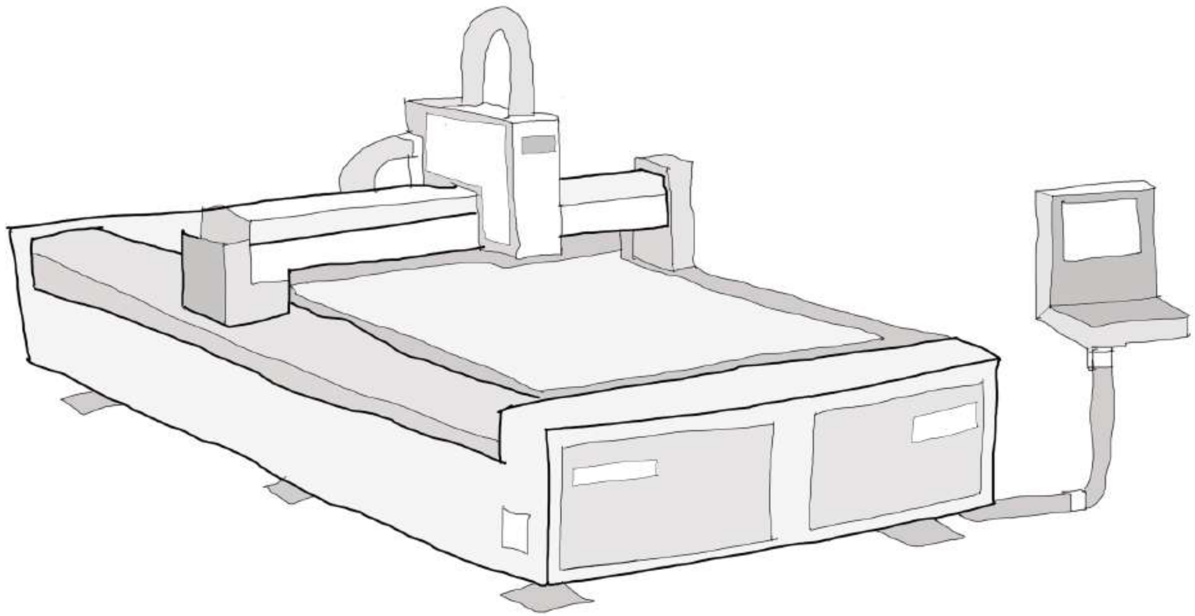


Fig 2.5(iii): *Diagram of a Laser Cutting Machine (Author 2020)*

HOW DOES IT WORK?

This process of digital manufacturing is largely 2Dimensional in its operation. The laser cutter works by cutting out CAD drawings that would be represented as 2Dimensional line drawings. According to the various type of line properties, the laser cutting machine varies the depth and intensity of the cut. Laser cutting technology is a relatively simple but highly effective technology that can be used to build 3D models through assembly. The main difference between laser cutting and 3D printing is that laser cutting creates separate pieces and elements that will require being built up whereas 3D printing translates a 3D CAD model into 3D form seamlessly. Laser cutting is comparatively a less sophisticated technology but has the advantages of being cheaper and more accessible. Affordabilty becomes an important factor in its adoption.

TYPES OF LASER CUTTING.

Sublimating

The material is removed primarily by evaporation due to the high intensity of the laser radiation in the cut area.

Melting

The material is melted by a laser beam in the cut area and blown away by an auxiliary gas. Mainly metallic materials are cut using this process..

Burning

A laser beam heats the material to its ignition temperature, so it can burn in an axothermic reaction with the reactive gas.

CO2 LASER CUTTING SYSTEMS.

C02 Laser cutting is a two-dimensional machining process that involves the removal of materials by high-intensity beam focusing on the workpiece. The laser beam melts or evaporates the workpiece in the thickness or depth direction of materials. Refer to **Fig 2.5(v)**. The molten material is blown away using an assistant gas. In the laser machining, unlike traditional methods, material removing is almost conducted without applying any force, (Moradi et al, 2018).

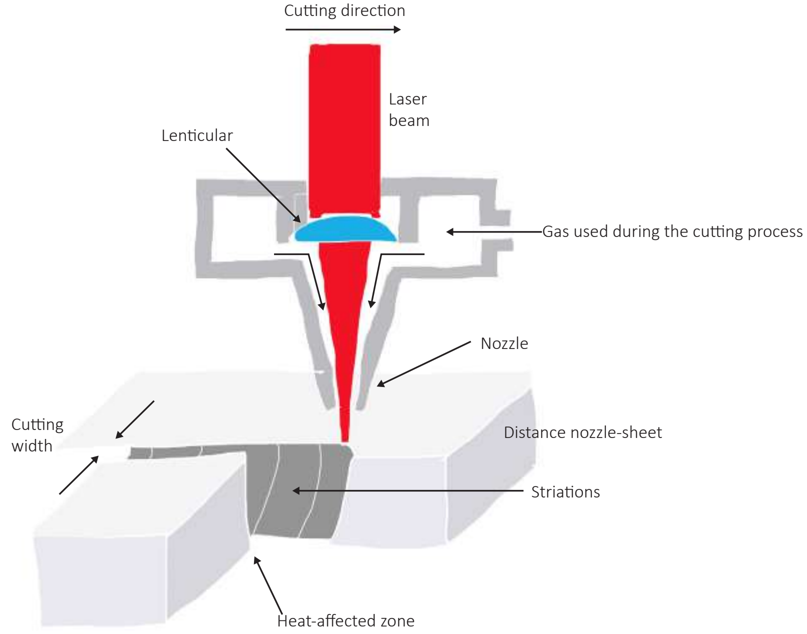


Fig 2.5(iv): *Diagram showing how a C02 Laser Cuting Machine Works (Author 2020)*

HOW DOES IT WORK?

A CO2 laser operates using gas. This mechanism of printing is run using electricity. The electric current is transmitted through a gas-filled tube and resultantly produces light. Reflective mirrors are at the ends of the tubes and they allow limited light to pass. The gas mixture is generally comprised of carbon dioxide, helium, hydrogen and nitrogen. CO2 lasers produce light that is invisible because it falls in the infrared range of the light-spectrum. “When stimulated by electric current, nitrogen molecules in the gas mixture become excited, meaning they gain energy. Nitrogen is used because it can hold this excited state for long periods of time without discharging the energy in the form of photons, or light. The high-energy vibrations of the nitrogen in turn excite the carbon dioxide molecules,” Badoniya 2018.

Bodaniya 2018 goes on to explain that after the carbon dioxide molecules are excited, “the laser achieves a state called population inversion, this is when the system has more excited particles than none excited ones.” CO2 laser printing is widely popular because it is powerful and extremely precise. It has a wide range as it can be used to cut many materials, including cloth, wood and paper. Metals and steel can also be cut by very specialised CO2 machines. This point is further expounded by Bodaniya 2018 who states that “Laser beam cutting is most commonly used for the cutting of different categories of materials because it is superior to any cutting method due to material versatility, high material utilisation and production flexibility, precise cuts with,faster cutting process and better accuracy.

2.6 Limitations of Digital Manufacturing

(i) SPEED & REABILITY

Additive manufacturing despite its advantages is still relatively in the development stages. Most of its perceived revolutionary characteristics have not been proven in industry and amongst other issues the printing process takes considerably longer than traditional manufacturing. Speed and reliability are one of the key drivers of competitive production, as a result of the current slow production speeds of additive manufacturing it is not a viable alternative to the current system. Gartner, (2012) argues that "3D printing is at peak inflated expectation, noting that the technology is still too immature to satisfy high expectations". It is a possibility that industry is overestimating the capabilities of the technology because it still in the experimental stages. However, current trends and projections focusing on the potential disruptive effects of 3D printing technology point towards a making "revolution" in its infancy. The current limitation of "slow production speeds", is something that can be expected in the inception of any technology, with further research and development, one can safely assume that its only a matter of time before production speed meets industry expectation.

(ii)LACK OF STANDARDISATION

The lack of standardisation patterning to both quality control and consistency is one of the issues that currently act as a hindrance to the adoption of additive manufacturing on an industrial scale. The opening up of the manufacturing industry beyond experts means that there is no control of the quality of products being produced and perhaps sold into the market. Several questions arise as a result of this challenge. Specifically, what role will the current industry play in restricting consumer creativity? To what extent should current manufacturers resist and repress the freedom to "make" enabled by the digital manufacturing revolution? These questions open debates and discussions on the complexity of digital manufacturing technology. However, what is clear is that removal of previous barriers to new entries in manufacturing fuels creativity and questions the rigidity of established manufacturing institutions. Additive manufacturing is disruptive by its nature and perhaps the real question is that "who makes up industry standards and are they even necessary?". To elaborate by completely liberalising the making process perhaps standardisation and quality control is left to the consumer, who will determine the quality based on their individual want and needs.

(ii)CHALLENGES TO INTELLECTUAL PROPERTY

Another potential limitation of digital manufacturing is that there is little or no protection of intellectual property. A vital component of the former is the independence of distributing CAD models online. The same freedom can be problematic as there are high chances of sharing illegal, protected, and unofficial CAD models, which in turn can be printed anywhere. Resultantly, piracy and illegal downloads of "designs" are issues that will evolve with the growth of 3D printing. However, the potential benefits of 3D printing outweigh the limitations relating to intellectual property.

In other words, the sharing of CAD models virtually dissolve the constraint of distance and time enabling greater exploration and experimentation. Simpson et al (2013) argue that "Bursts of innovation happen when an emerging technology removes a once prohibitive cost, distance and time." To sum up, the protection of intellectual property cannot be guaranteed in the virtual space and this problem is not unique to digital manufacturing. At the same time the innovative potential enabled by sharing in the virtual space is a unique opportunity that must be fully utilised.

2.7 Implications of Digital Manufacturing on Architecture & Construction

The dawn of digital manufacturing will result in the reincarnation of the architect master-builder. This is because digital manufacturing blurs conventional design and making roles resulting in the dissolution of specialisation. To expound, conventionally separate roles of building design and construction are set to merge and integrate leading to the rebirth of the architect who is not only a designer of space but also craftsman and sculptor of built form. Master-builder is a term last applied in the renaissance period referring to a building specialist expert who was well invested in both the theoretical planning and physical realisation of building design. The digital manufacturing revolution re-engages the designer with the act of making though CAD models and fabrication This newly founded synergy between handcraft, digital design and fabrication is empowering to the architect who is afforded control in conceptualisation and making previously seen in the era of the master-builder.

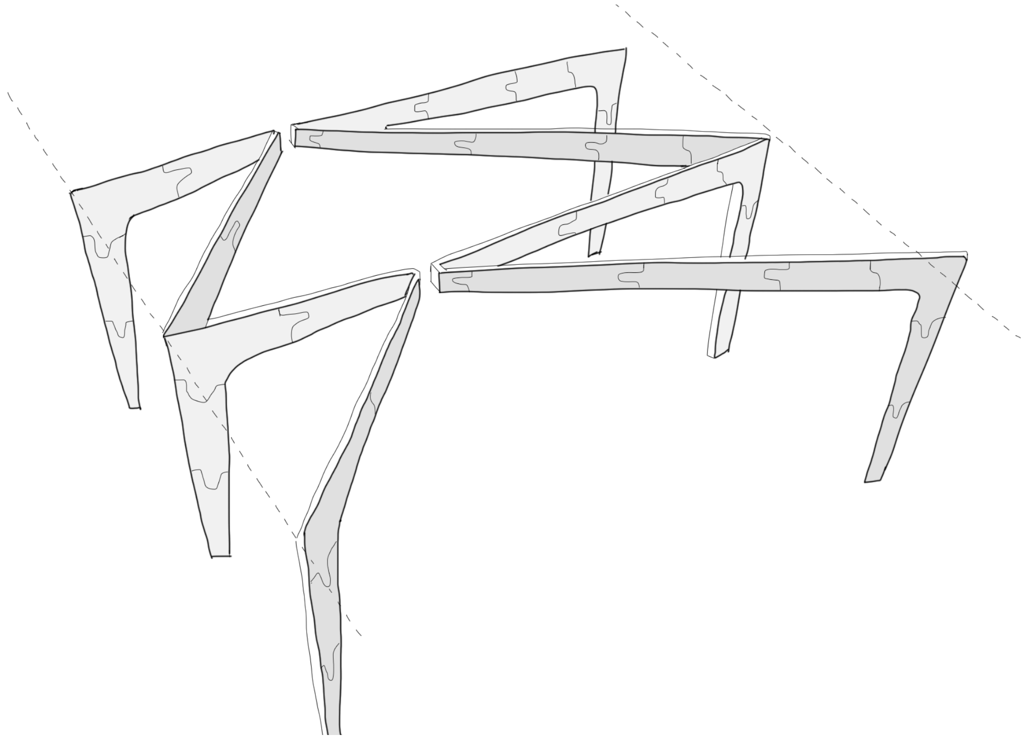


Fig 2.6(i): *Fabricated LVL Wood Construction ,Earthworld Architects "Future Africa Campus" Pretoria, South Africa (Author 2020).*

This new form of designing and making architecture will see a shift from the heavy and messy construction technology of concrete and steel to the more succinct fabrication and assembly of engineered wood and polymers. The digital fabrication technology is a manifestation of "disruptive innovation" as it also raises consciousness on environmental issues and sustainability. Put into context, the author proposes a design that uses digital fabrication and assembly as a method of framed construction. This way of making a building affords the architect more design control, hence a greater responsibility to respond in an environmentally sustainable manner. Consequently, most of the design proposal will be made from sustainable material such as Ethylene Tetrafluoroethylene (ETFE), a product of recycled plastic, and Cross Laminated Timber (CLT). In relative comparison to concrete and steel timber has lower embodied energy, as well as higher strength to weight ratio, making it an ideal material for both framed construction and a sustainable agenda.

The two main materials (ETFE), mainly used for the roof and facade membrane and (CLT), which will form the main structure and wall panels are currently not being made locally, which offers an opportunity to use local expertise and resources to develop these materials using digital manufacturing technology. Since, the chosen site is currently an operational building used for light industry (service cars), the construction of the "design proposal" will be phased perhaps in such a way that some of the prefabricated elements for the proposal are manufactured in the existing building. In other words, the design proposal aims to fully utilise available resources such as manpower, existing infrastructure, and expertise. This will result in the full utilisation of available resources, hence contributing to the sustainable agenda in a positive manner. This new way of construction has precedent in South Africa as it has already been implemented by Earthword Architects in the design of the New Africa Campus in Pretoria, refer to Fig 2.6(i).

CASE STUDY
Future Africa Campus (Pretoria)

The advent of digital manufacturing has signalled more involvement by architectural designers in how buildings are constructed. This new found relationship between design and making has launched an era in which new materials, such as wood, which is more malleable and ecologically sustainable have become more prominent. This methodology is evident in the construction of the University of Pretoria's "Future Africa Campus Dinning Hall", refer to Fig 2.6(ii) illustrating the structure designed by Earthworld Architects (2018).In this case the building is put together through prefabricated building elements which are manufactured digitally by a network of local suppliers, who are in some instances new entrants into the industry. The prefabricated components are assembled on site and the building process becomes quick and efficient. In other words "Building construction becomes an act of assembling and integrating a pre-manufactured puzzle,"(Eksteen 2018).

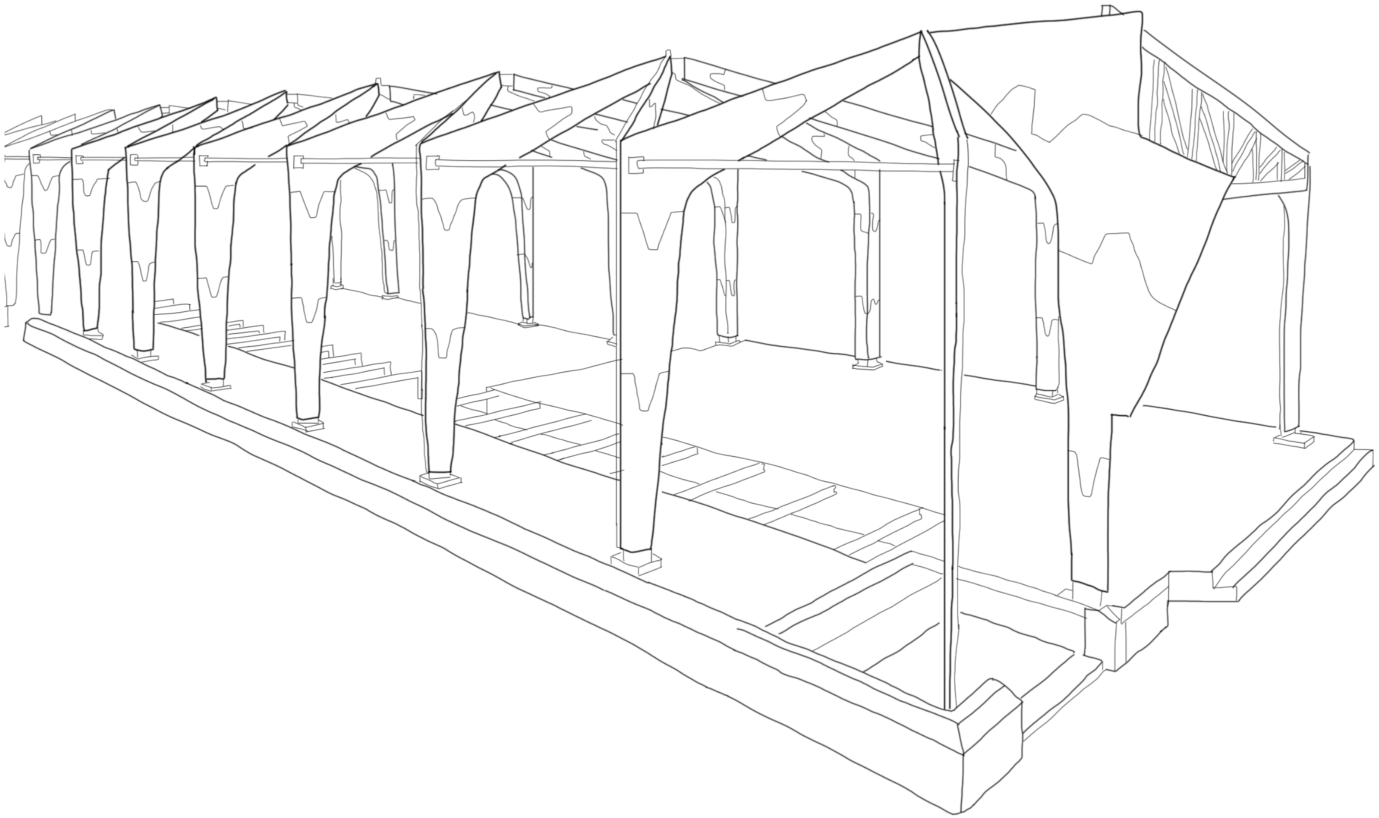


Fig 2.6(ii): *Prefabricated Timber Frame Construction ,Earthworld Architects "Future Africa Campus" Pretoria, South Africa (Author 2020).*

End of Chapter

Chapter 3
Site Analysis .

SYNOPSIS

This chapter marks a departure from theory and conceptual discourse to a more visual and graphic dialogue. The primary objective of the graphics supported by explanatory text is to explore the site and its greater context. The main theoretical findings of chapter 1 and 2 are applied in the analysis presented in chapter 3. The chapter seeks to explore linkages, relationships and connections between entities that can ultimately influence the design proposal. The introduction of site through drawings, diagrams and photography forms the basic platform upon which the architectural explorations will be based.

3.1 Urban Scale Mapping

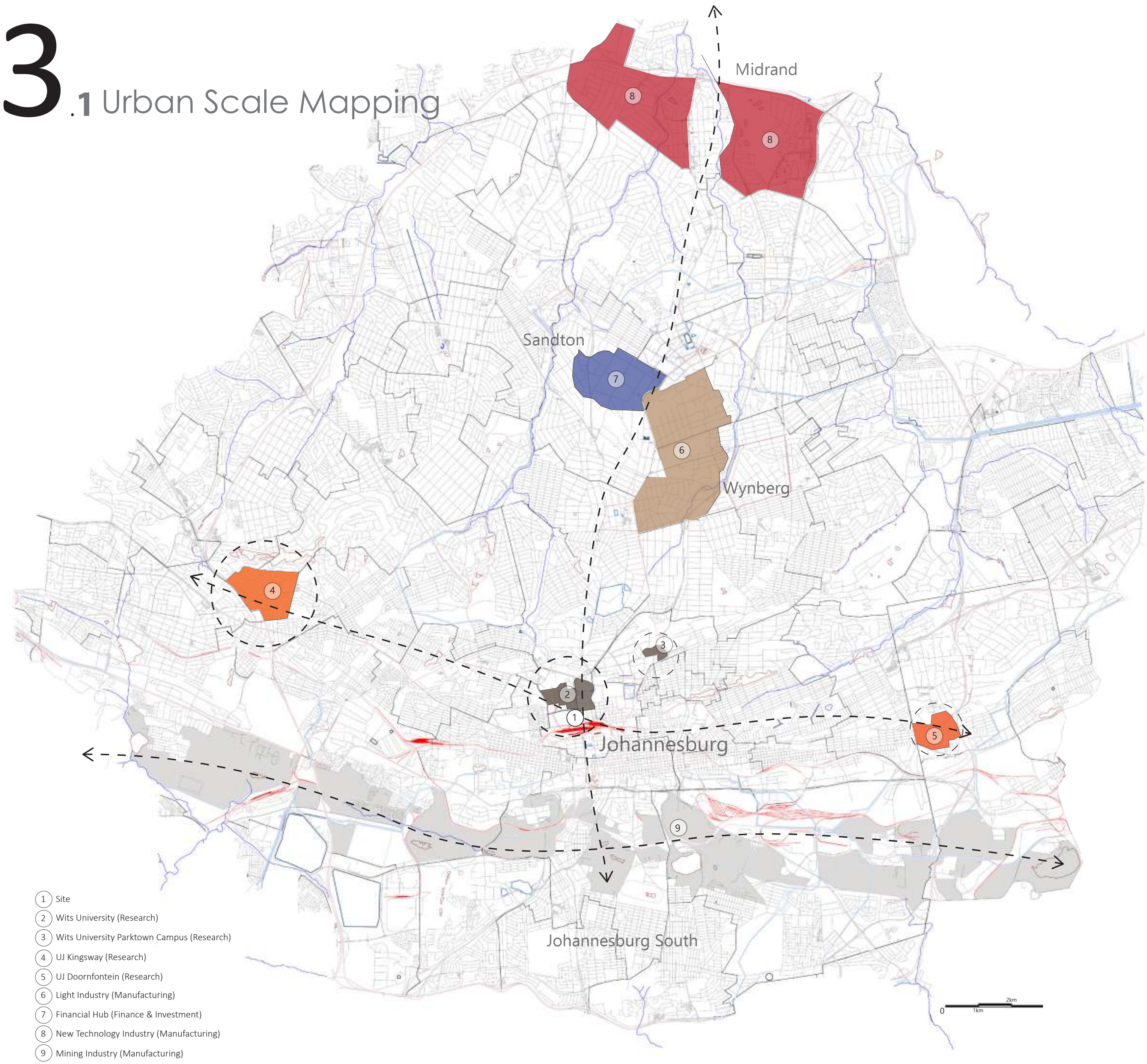
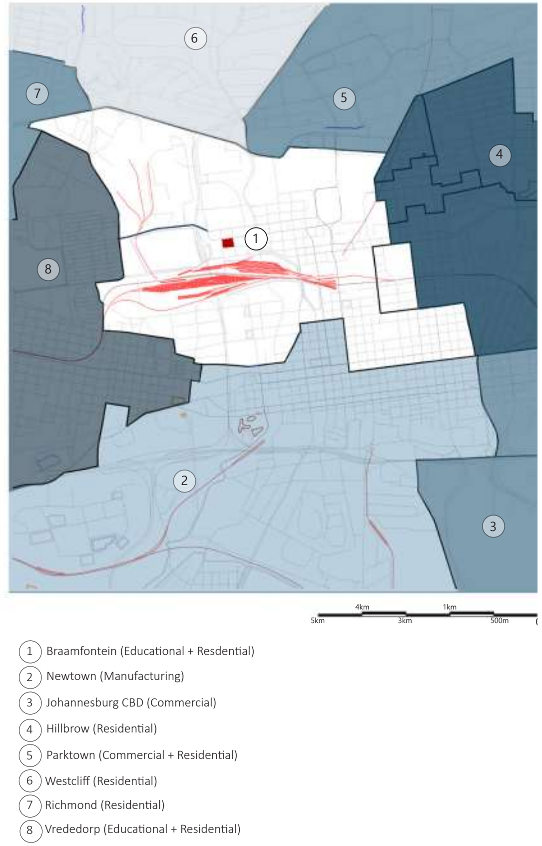


Fig 3.1(i): *Map of Johannesburg City Metropolitan and Intersection Analysis, (Author 2020).*



CITY INTERSECTIONS
Knowledge & Industry

This locality map explores the relationship between traditional manufacturing where the initial goldmines where located and the modern day financial industry based in Sandton. it can be deciphered from the map that industry is located along a vertical stretch from north to south which is intersected by the east to west educational corridor where there is knowledge generation. This makes the location of site central.

CITY INTERSECTIONS
Mobility & Connectivity

The Diagram highlights the main transit nodes that connect Braamfontein with its immediate urban context. In particular special attention is paid to the proximity of the chosen site to other significant modal hubs mainly Park Station and taxi ranks.

It can be observed from **Fig 3.1(ii)** that there is a direct correlation between the population density of an area and the placement of public transport stations. More importantly the chosen site is located within a 5km radius of all the major public transport stations, but far enough to enable the design and implimentation of a productive space such as a factory.

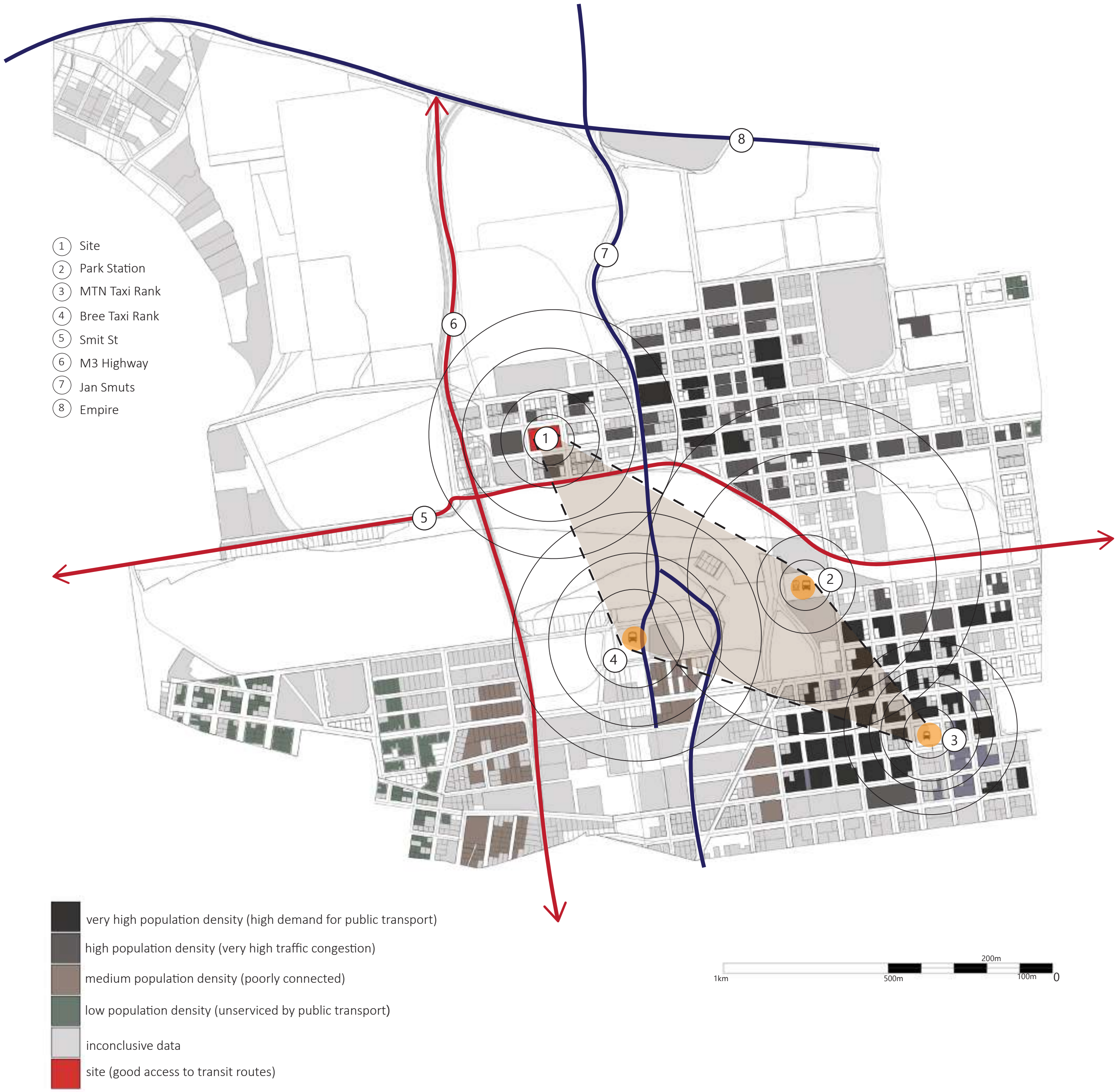


Fig 3.1(ii): *Urban Scale Diagram of Connection Nodes linked to Braamfontein , (Author 2020).*

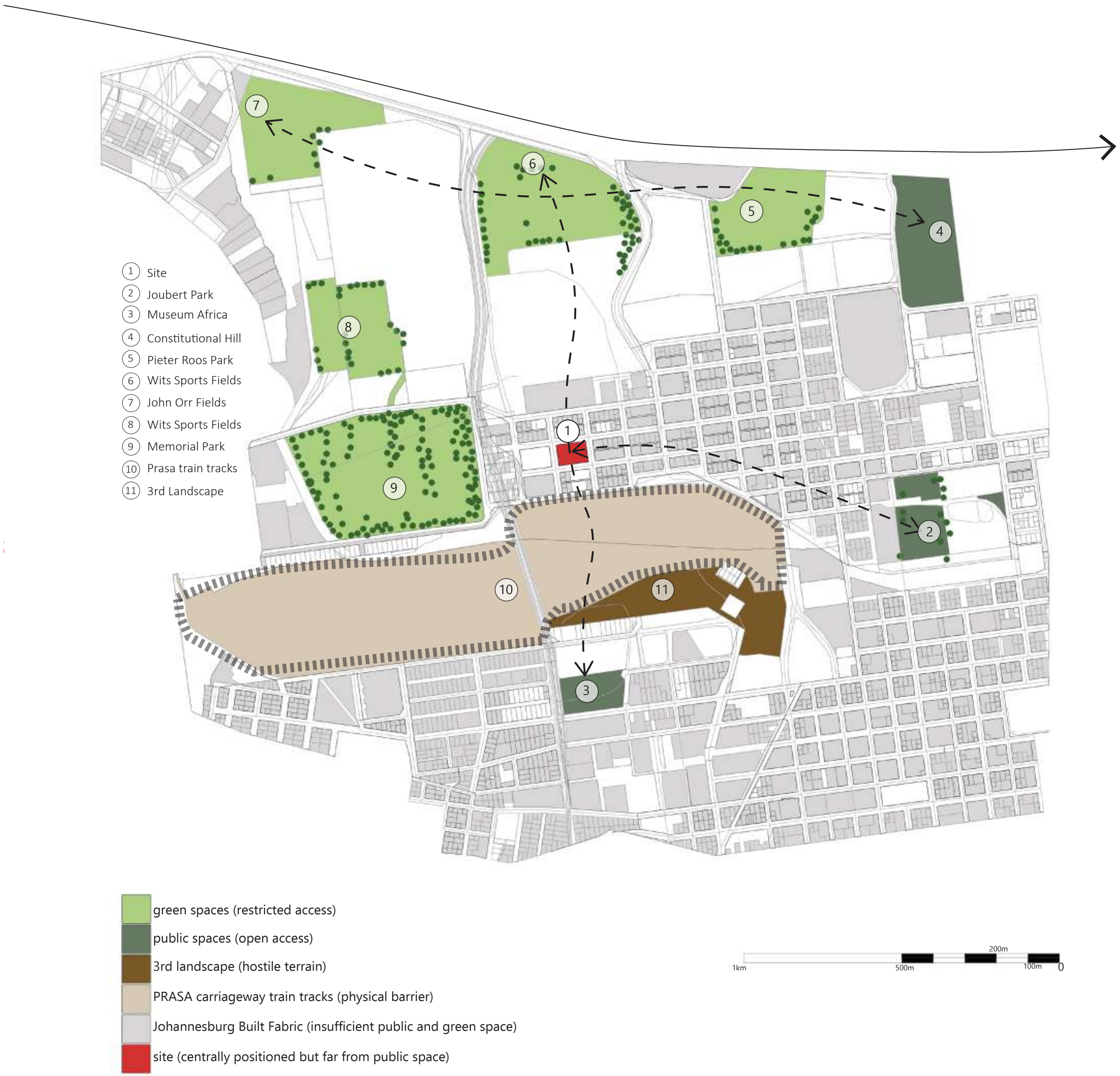


Fig 3.1(iii): *Urban Scale Diagram of Public and Open Spaces in the greater Braamfontein region , (Author 2020).*

CITY INTERSECTIONS
Open & Green Spaces

The Diagram **Fig 3.1(iii)** shows the open green space availaible in relative to the built up space in the greater Braamfontein and Central Business District. The aim is to establish linkages between site and public green space, which are necessary for recreation around the proposed factory.

The analysis shows that there is very little available public and green recreational space around site. The University of the Witwatersrand is closed off to public access and the PRASA railway station creates a hostile landscape. There is need for site and proposed building program to engage and open up the university as well as create a focal public space within its vicinity.

CITY INTERSECTIONS
Locality & Transit Nodes

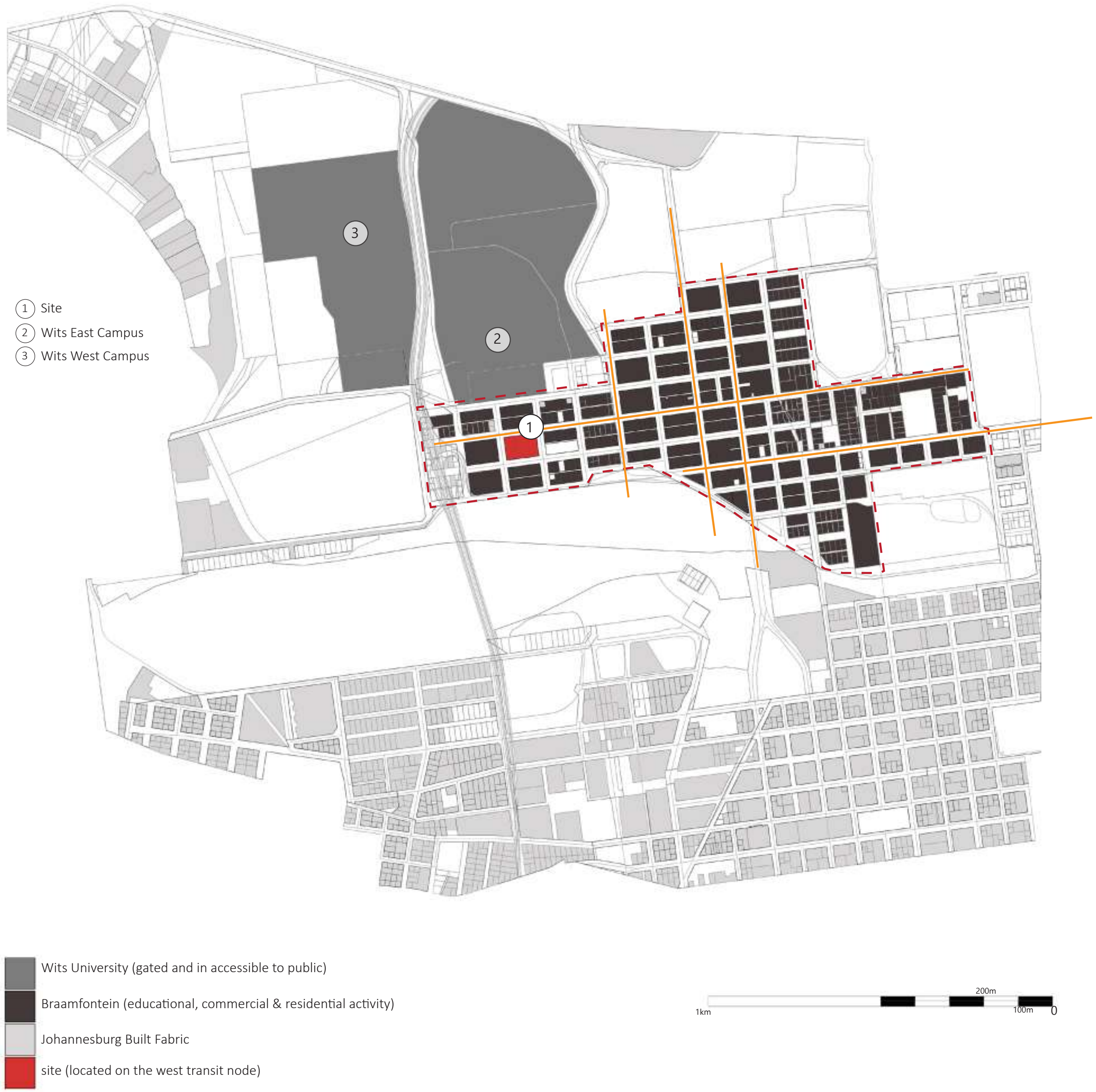


Fig 3.1(iv) shows the routes that connect Braamfontein, in particular the focus is on Wits University as a landmark and the major avenues that are used by public transport.

From the diagram it can be deciphered that Jorrisen street forms a major avenue of ingress into Braamfontein and the city. How can an architectural intervention tap into the rich potential of a transit landscape? It can also be deduced that De korte street is a relatively busy outlet. If the proposed design is placed on the edge of this route, is it possible to slow down movement along this avenue and allow a moment of pause and interaction?

Fig 3.1(iv): *Urban Scale Diagram showing the major Transit Routes and Landscapes in Braamfontein , (Author 2020).*

CITY INTERSECTIONS

Knowledge Economy

Fig 3.2(i) shows the Educational Corridor which passes through Braamfontein and Site. It can be observed that Site is strategically located in the centre. The proposed Digital Manufacturing Factory driven by innovation can tap into the rich knowledge economy that can be found in the vicinity.

University of Johannesburg (Experimental & technical)
University of the Witwatersrand (Research intensive)
Corporate Companies
Tertiary Colleges (business management & IT)
Johannesburg Built Fabric
site (centrally located on the educational corridor)

200m
1km 500m 100m 0

Fig 3.1(v): *Urban Scale Diagram of the Education Corridor and Knowledge Generation enteties in Braamfontein , (Author 2020).*

3.2 Site Analysis

LOCALITY MAP
Access and Proximity

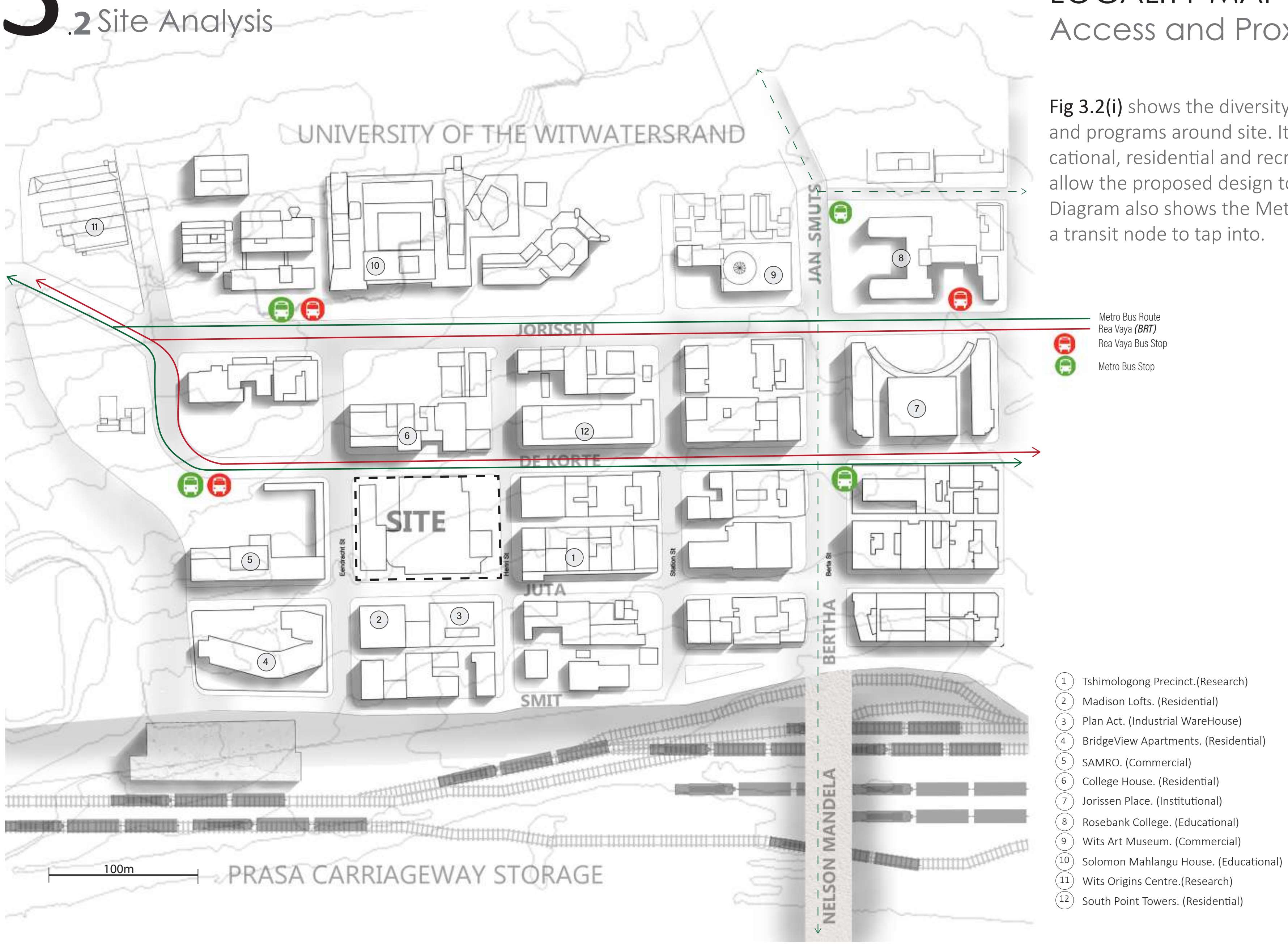


Fig 3.2(i) shows the diversity in function of the buildings and programs around site. It is a mix of commercial, educational, residential and recreational. This versatility will allow the proposed design to have a civic interface. The Diagram also shows the Metro Bus and Rea Vaya Routes, a transit node to tap into.

Fig 3.2(i): *Locality Map of Braamfontein West , (Author 2020).*

3D LOCALITY MAP
Urban Built Environment.

1. Tshimologong Precinct. (Research)
2. Madison Lofts. (Residential)
3. Plan Act. (Industrial Warehouse)
4. BridgeView Apartments.(Residential)
5. SAMRO. (Commercial)
6. College House. (Residential)
7. Jorissen Place. (Institutional)
8. Rosebank College. (Educational)
9. Wits Art Museum.(Commercial)
10. Solomon Mahlangu House.
11. Wits Origins Centre. (Research)
12. South Point Towers.(Residential)

Fig 3.2(ii) illustrates the density of the urban environment in which the chosen site is located. This context has a different range of building typologies and a well connected developed urban infrastructure system that will have a limited impact on the existing eco-system. The chosen Site is an Existing V.W Retailer and Garage.

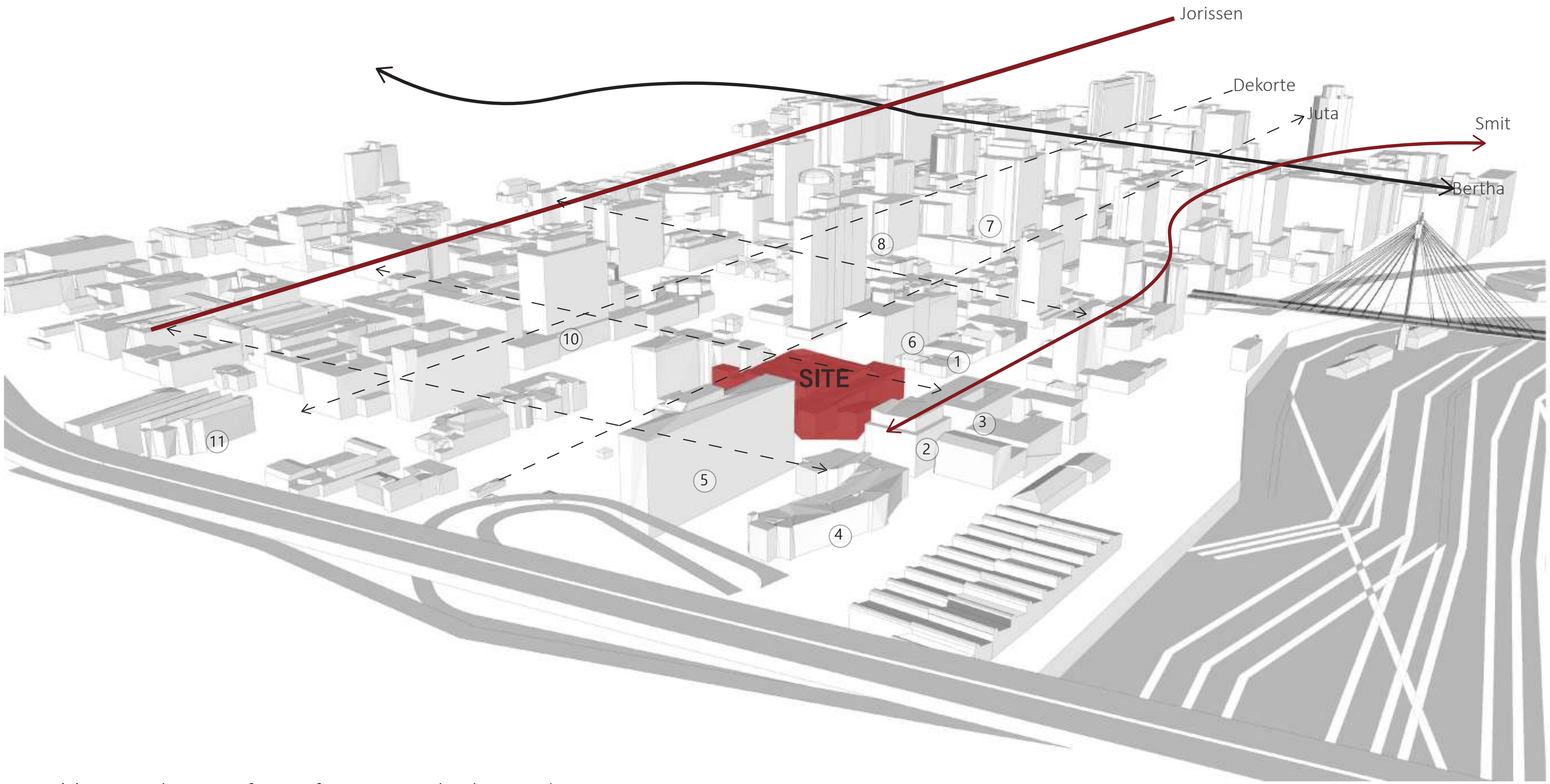


Fig 3.2(ii): *3D Locality Map of Braamfontein West , (Author 2020).*

Fig 3.2(iii):*"Urban hustle and bustle" Corner of VW Hatfield(Chosen Site) :Intersection DeKorte st and Henri st,Braamfontein, Johannesburg (Author 2020).*

Fig 3.2(iv): *" After the Rain", Image showing VW Hatfield on the backdrop of a relatively calm traffic along De Korte st :Intersection DeKorte st and Eendracht st, Braamfontein, Johannesburg (Author 2020).*

Fig 3.2(v): *“The drop off” Image showing man disembraking of a Rea Vaya Bus at a Bus Stop along De Korte st :Braamfontein, Johannesburg (Author 2020).*

Fig 3.2(vi):*"The desolate" Image showing a gloomy baren Juta st :Intersection Juta st and Henri st,Braamfontein, Johannesburg (Author 2020).*

Fig 3.2(vii):*"The Great Escape" Image showing late afternoon traffic congestion :Intersection Juta st and Henri st,Braamfontein, Johannesburg (Author 2020).*

Chapter 4
Responsive Design & Exploration.

SYNOPSIS
The primary focus of this chapter is to develop an intuitive experimental design proposal that is based on a response to contextual constraints and opportunities presented by the site. Physical modeling and prototyping is introduced as a complimentary method of design exploration. The aim of the responsive design explored in the chapter is by no means conclusive, it is a process meant to initiate design questions, conversations and ideas that can be developed and tested by design methodologies in subsequent chapters.

RESPONSIVE MAPPING
Existing Buiilding Analysis.

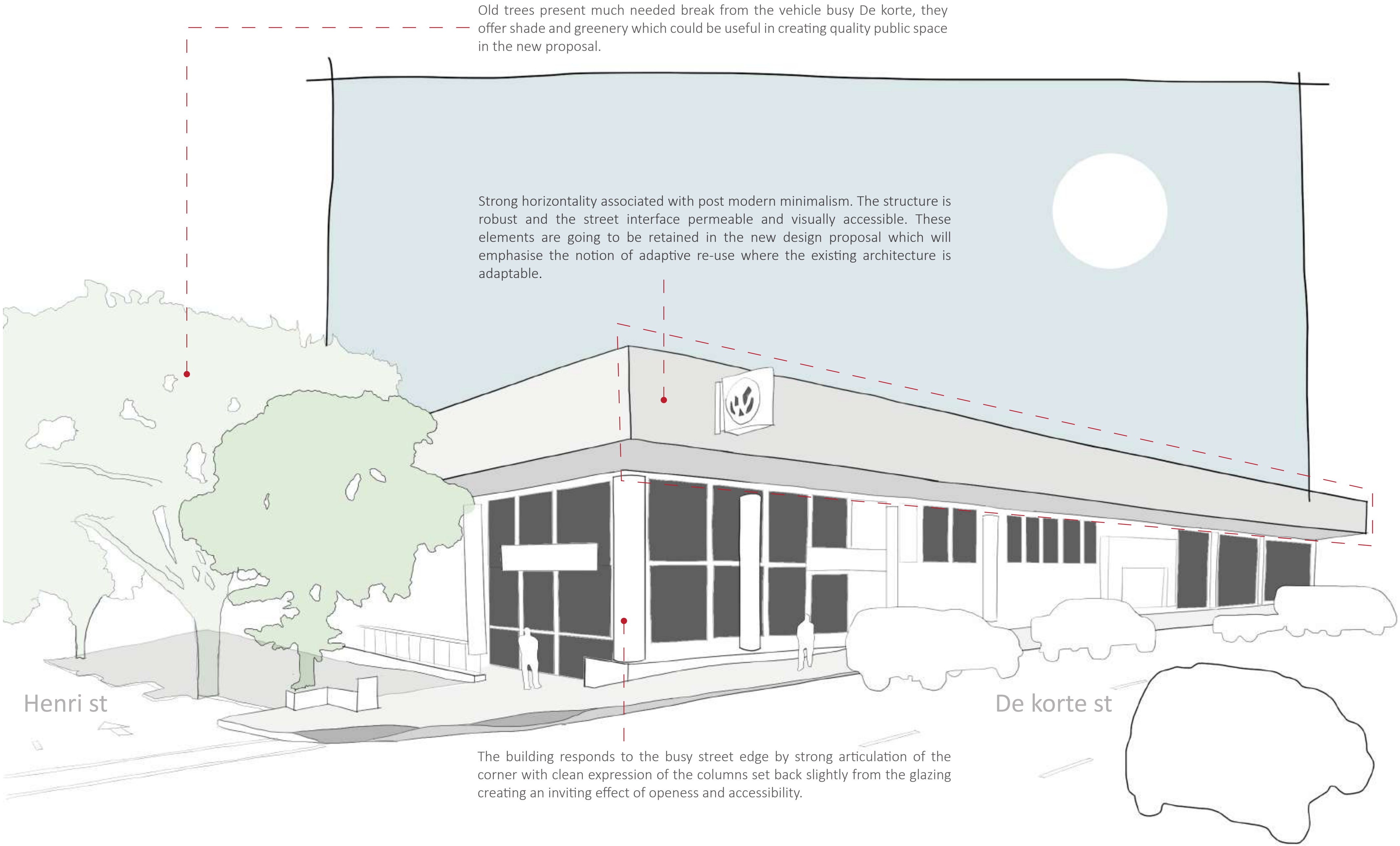


Fig 4.1(i):*Diagram Analysing the Existing Structure and Street Edge Corner De Korte and Henri, (Author 2020).*

RESPONSIVE MAPPING
Existing Building Analysis.

The boundary wall along Juta st in this case completely disconnects the street with the building. This is highly problematic as it creates the notion of exclusivity and mistrust. The design proposal reminds an open accessible edge to Juta st that is a backdrop to a pedestrian street.

This floating element feels inconsistent with the discipline and control of post modern minimalism. It is in sharp contrast to the interactive interface of De korte . This component is going to be demolished in the new building proposal.

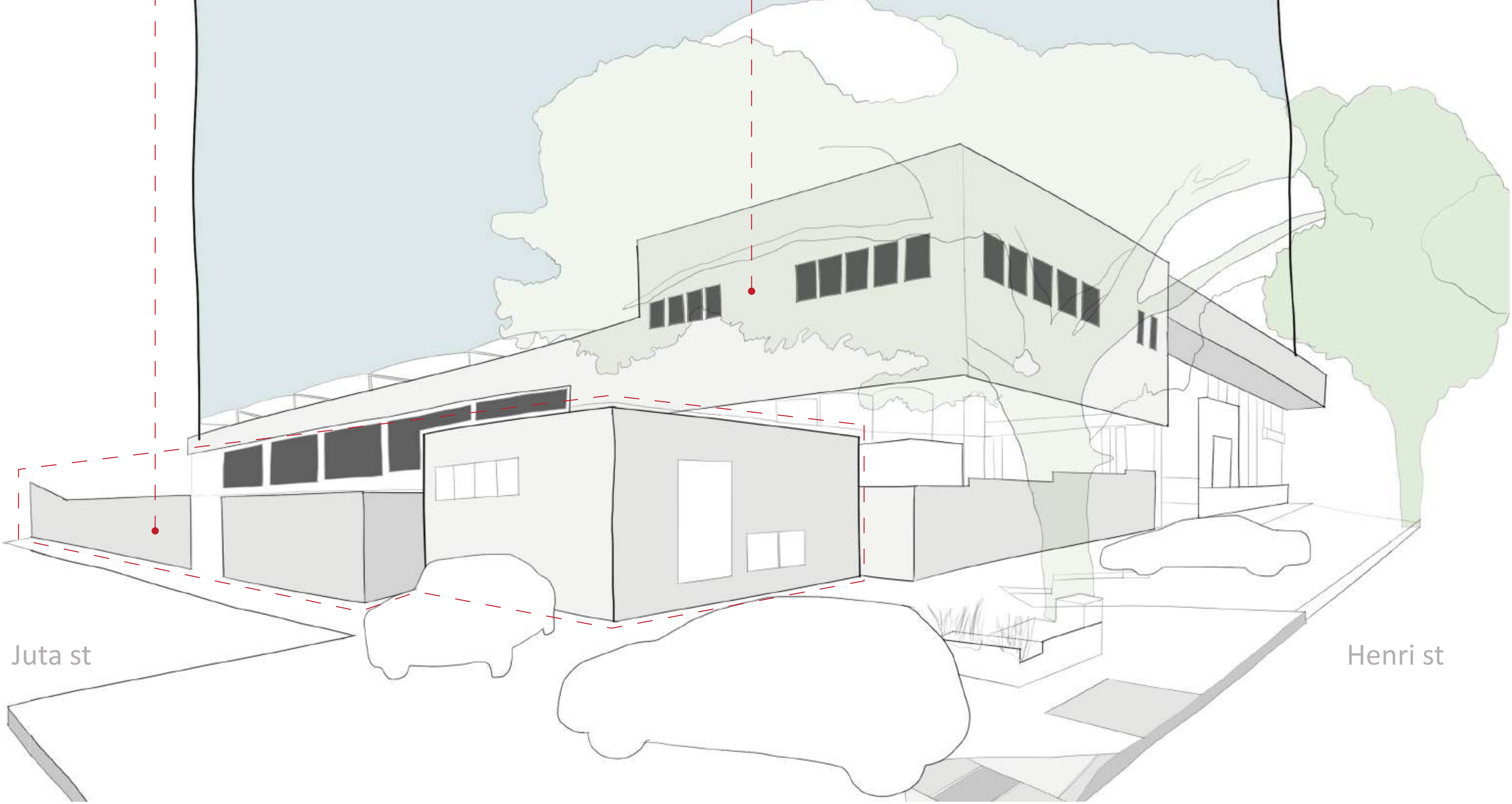
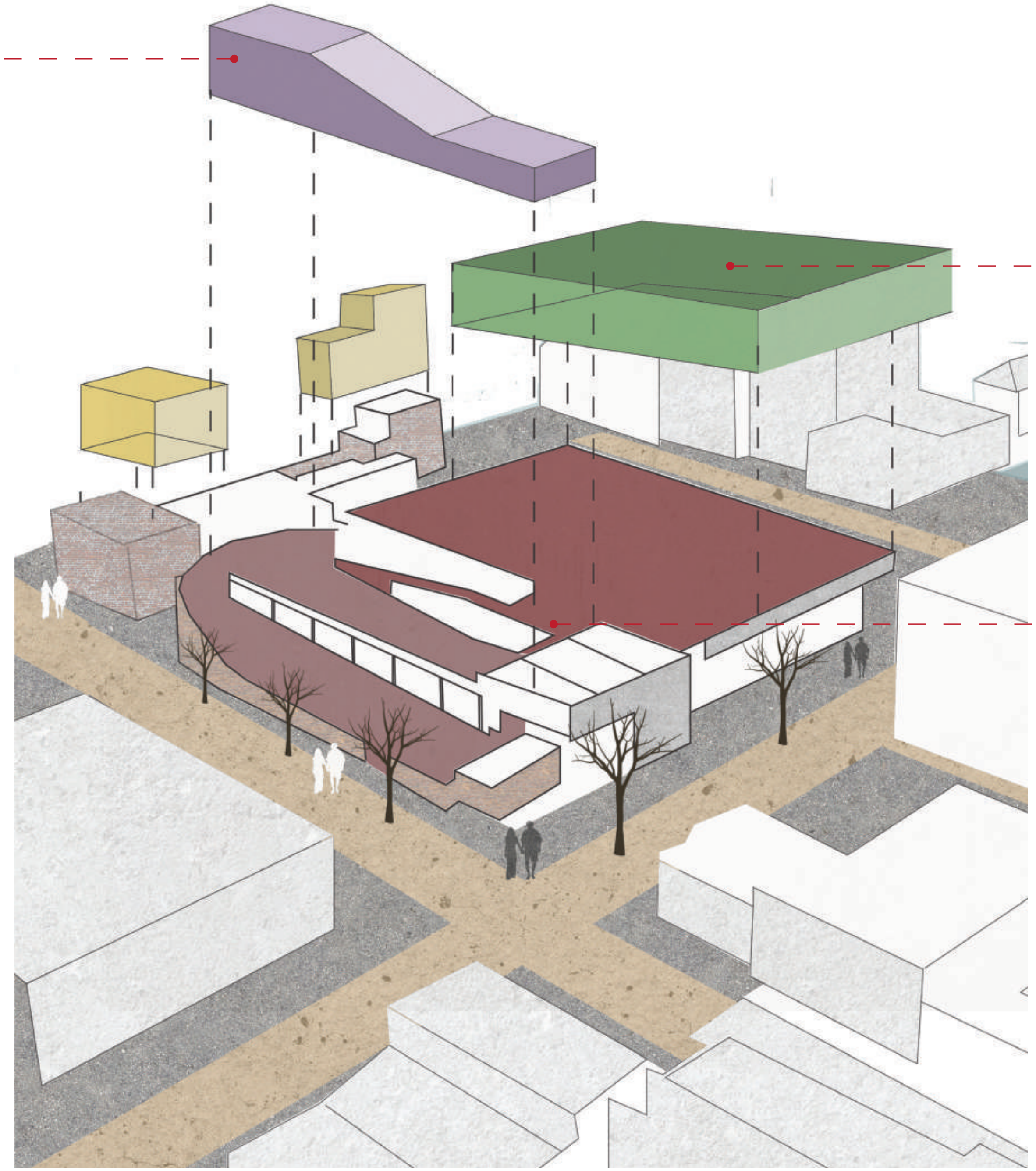


Fig 4.1(ii):*Diagram Analysing Street Edge Corner Juta and Henri, (Author 2020).*

SITE STRATEGY
Existing Building Analysis.



Some parts of the existing structure are going to be completely demolished to make way for a new architectural typology and expressions. This is because some of the elements are not structurally sound for re-use.

Elements of existing building that are structurally robust and can be repurposed will be incoorporated in the new scheme.

Existing VW Building will arguably become redundant in the near future as current trends point out to future with less vehicles due to vehicle sharing, more efficient public transport systems and a changing perception to personal vehicle ownership.

The existing is reimagined as a new typology "Digital Manufacturing Factory".

Fig 4.1(iii):*Diagram Analysing Existing Building and Proposed Site Strategy, (Author 2020).*

SITE STRATEGY
Existing Building Analysis.

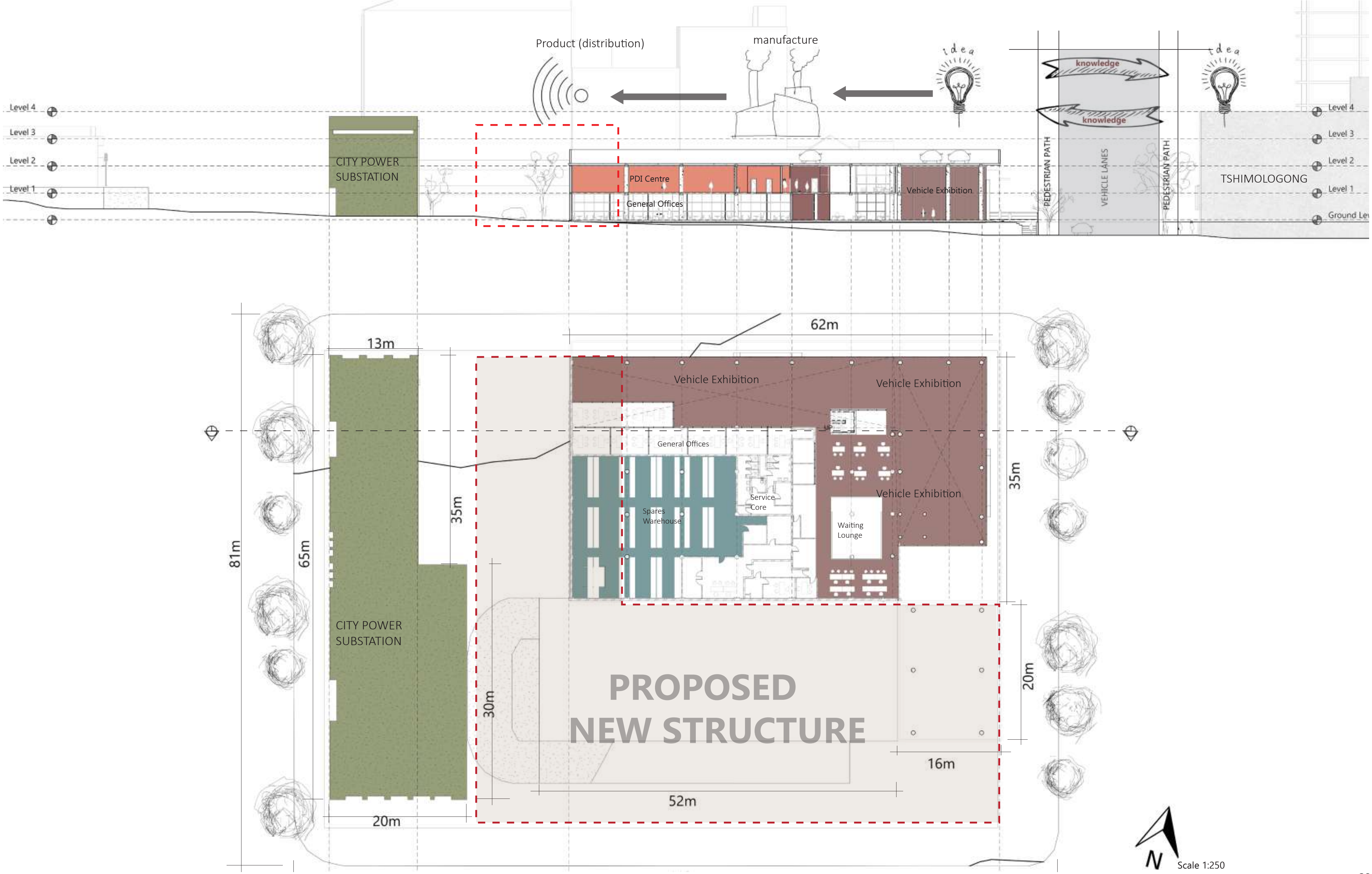


Fig 4.1(iv): *Plan and Section Drawing illustrating Existing Building and Proposed Site Strategy, (Author 2020).*

SITE STRATEGY
Existing Building Analysis.

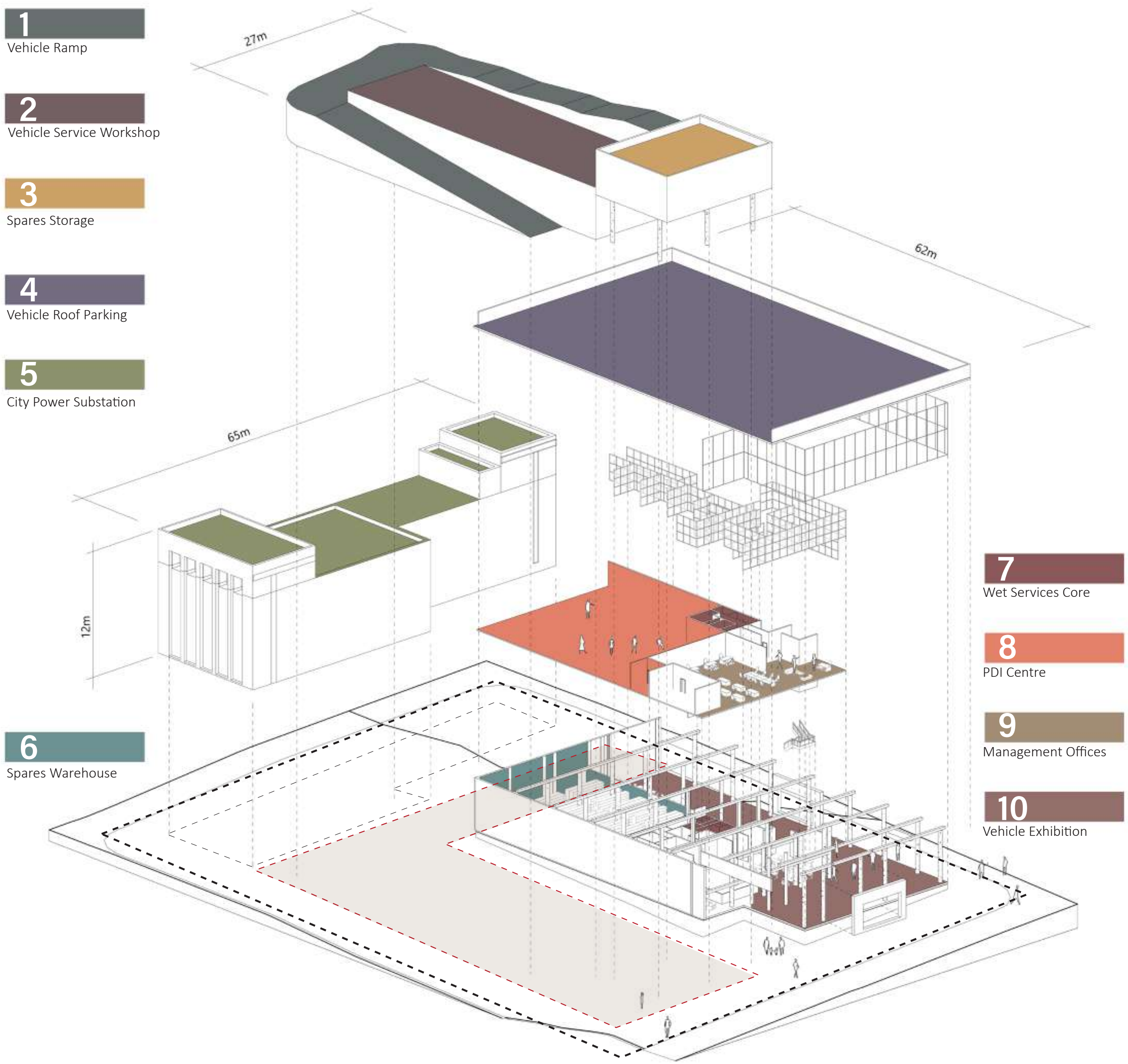
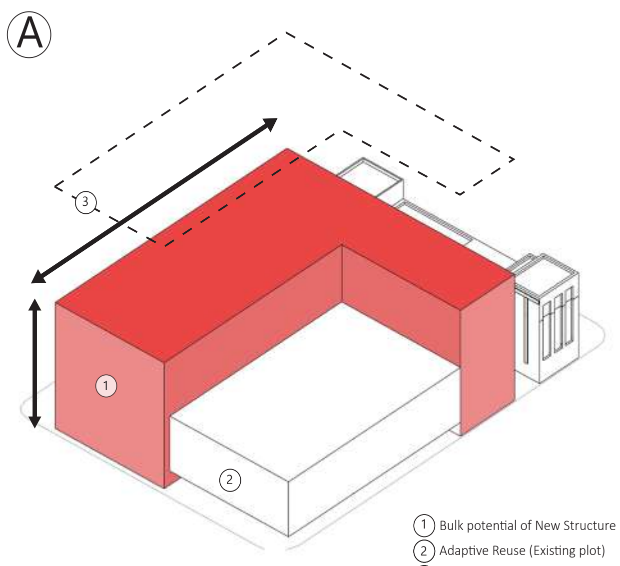


Fig 4.1(v): *Axonometric Drawing showing Existing Building and its Spatial layout , (Author 2020).*

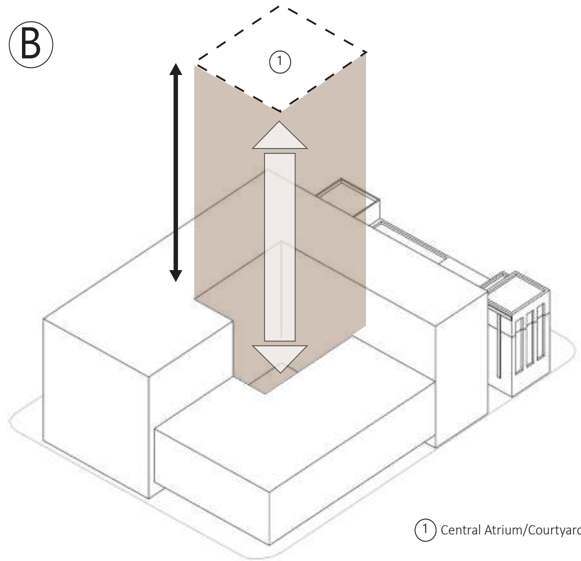
SITE RESPONSIVE DESIGN

Form Exploration (Massing).



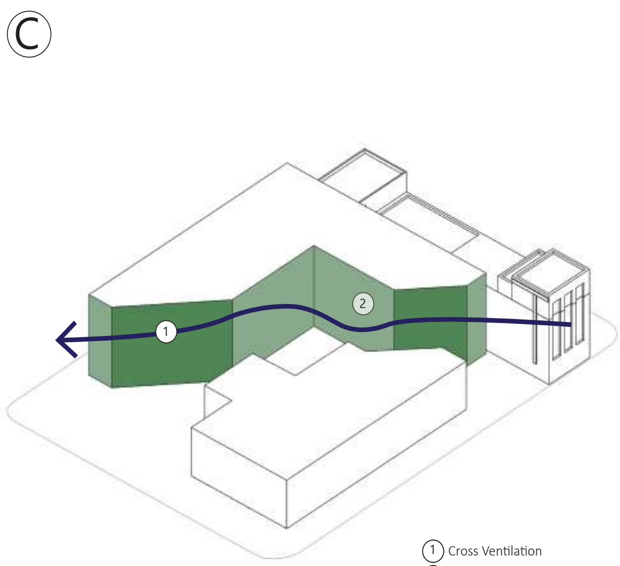
Bulk Site Potential

1. Bulk potential of New Structure
2. Adaptive Reuse (Existing plot)
3. New Structure Footprint



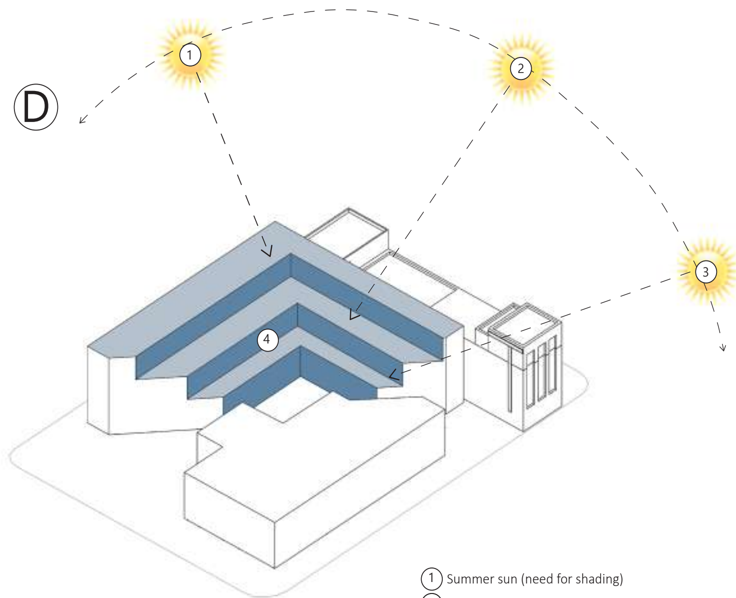
1. Central Atrium/Courtyard Cut-Away

Passive Climate Design (Natural Light)



Passive Climate Design (Movement)

1. Cross Ventilation
2. Natural Cooling



Passive Climate Design (Sun Studies)

1. Summer sun (need for shading)
2. Autumn & Spring Sun (comfortable)
3. Winter Sun (desirable)
4. Maximum solar exposure

Fig 4.1(vi): *Series of Diagrams Exploring Form based on Climate and Site Conditions , (Author 2020).*

SITE RESPONSIVE DESIGN
Form Exploration Collage.

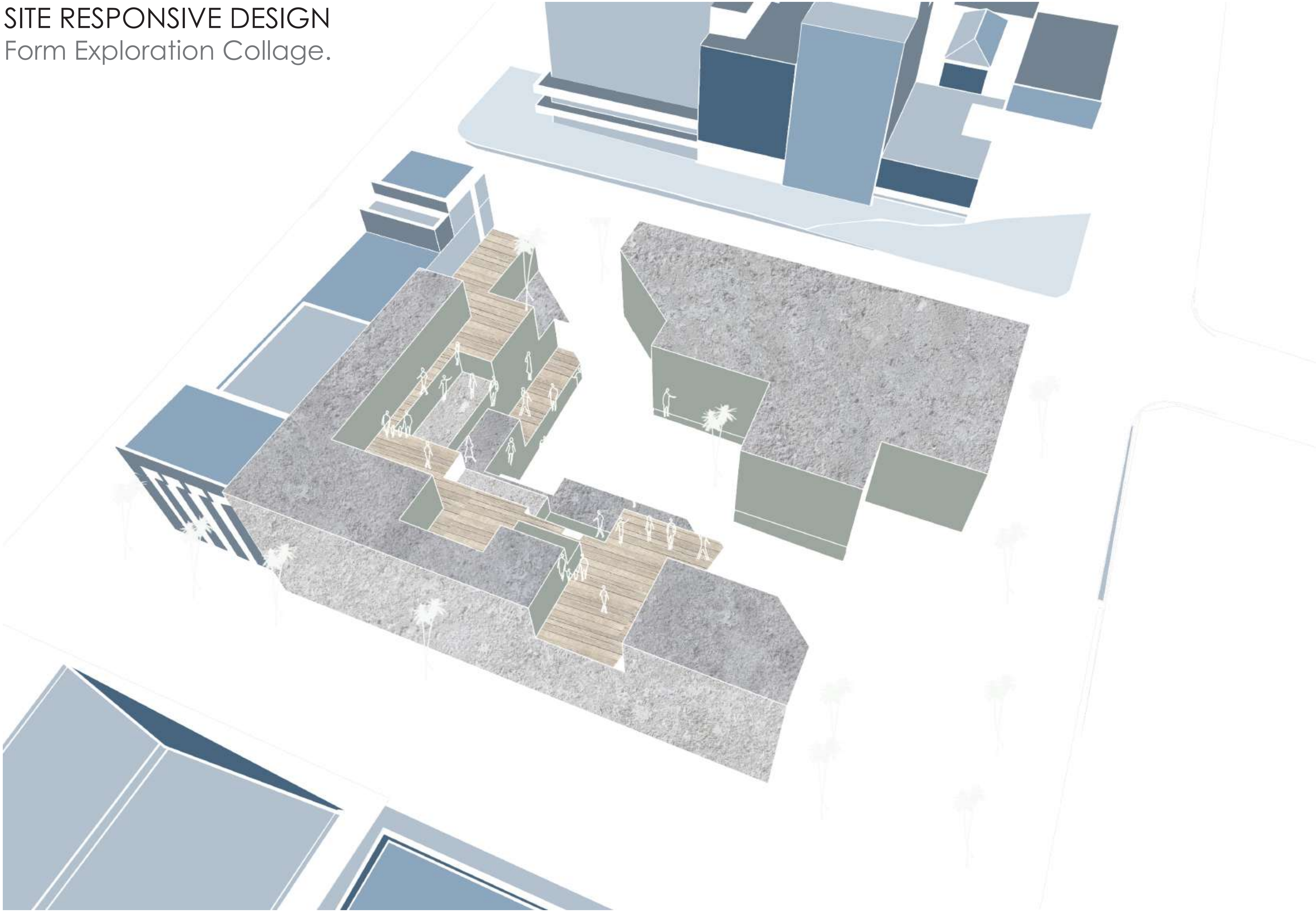


Fig 4.1(vi): *Artist's Impression of Form Exploration and Feel of Space created , (Author 2020).*

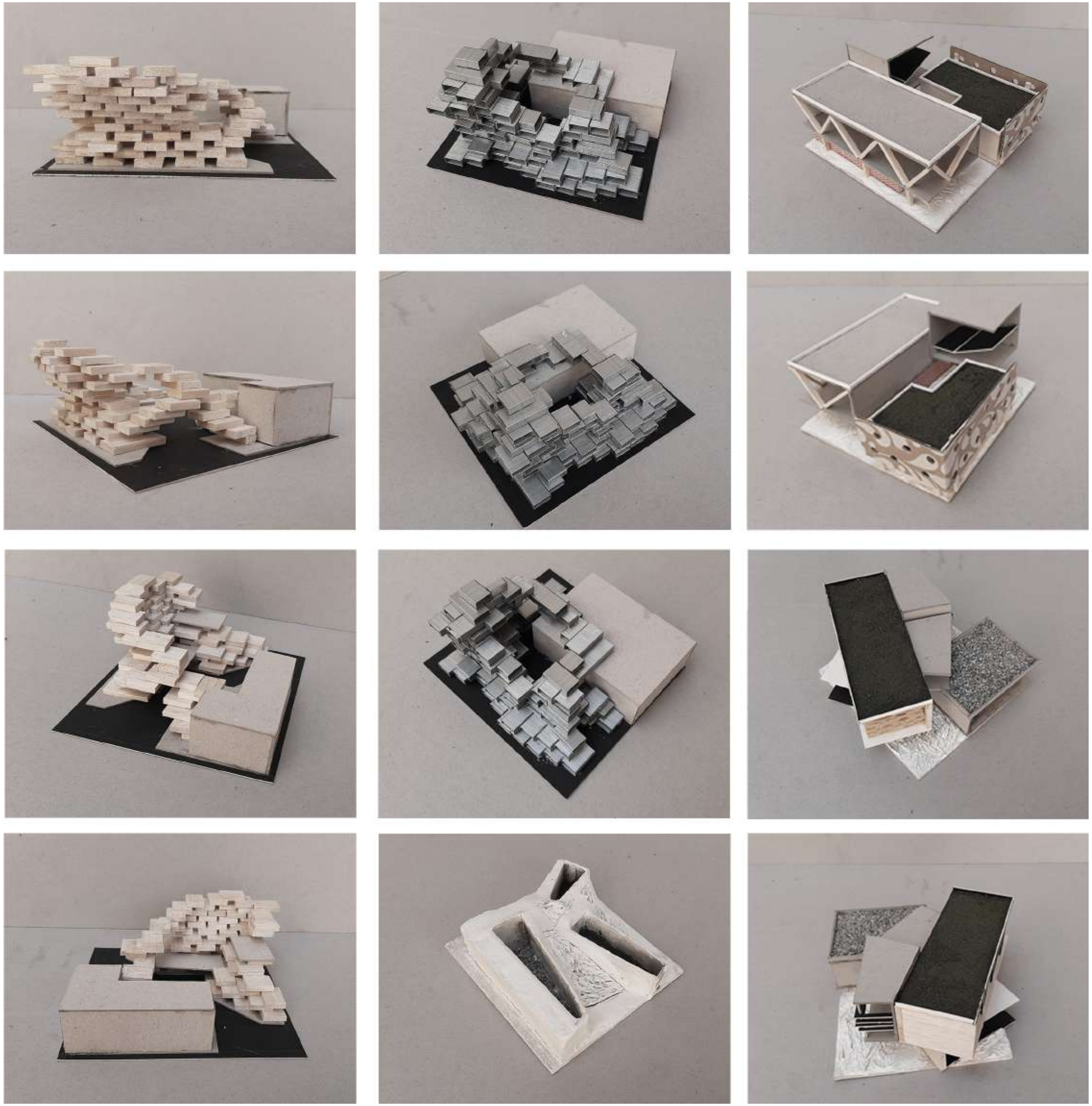


Fig 4.2(i): *Design Charrette Collage "Experimental Rapid Modelling" , (Author 2020).*

FORM EXPLORATION
Design Charrette.

Fig 4.2(i) explores the materiality, tectonics and form of the design proposal through a process of rapid production of various design iterations.

The process was particularly helpful in testing out ideas quickly and developing new ones at the same rate. By physically testing out concepts the feasible ideas gradually stand out and these get developed further into potential architectural form. The next few pages show detailed exploration of various concepts arising from the design charrette.

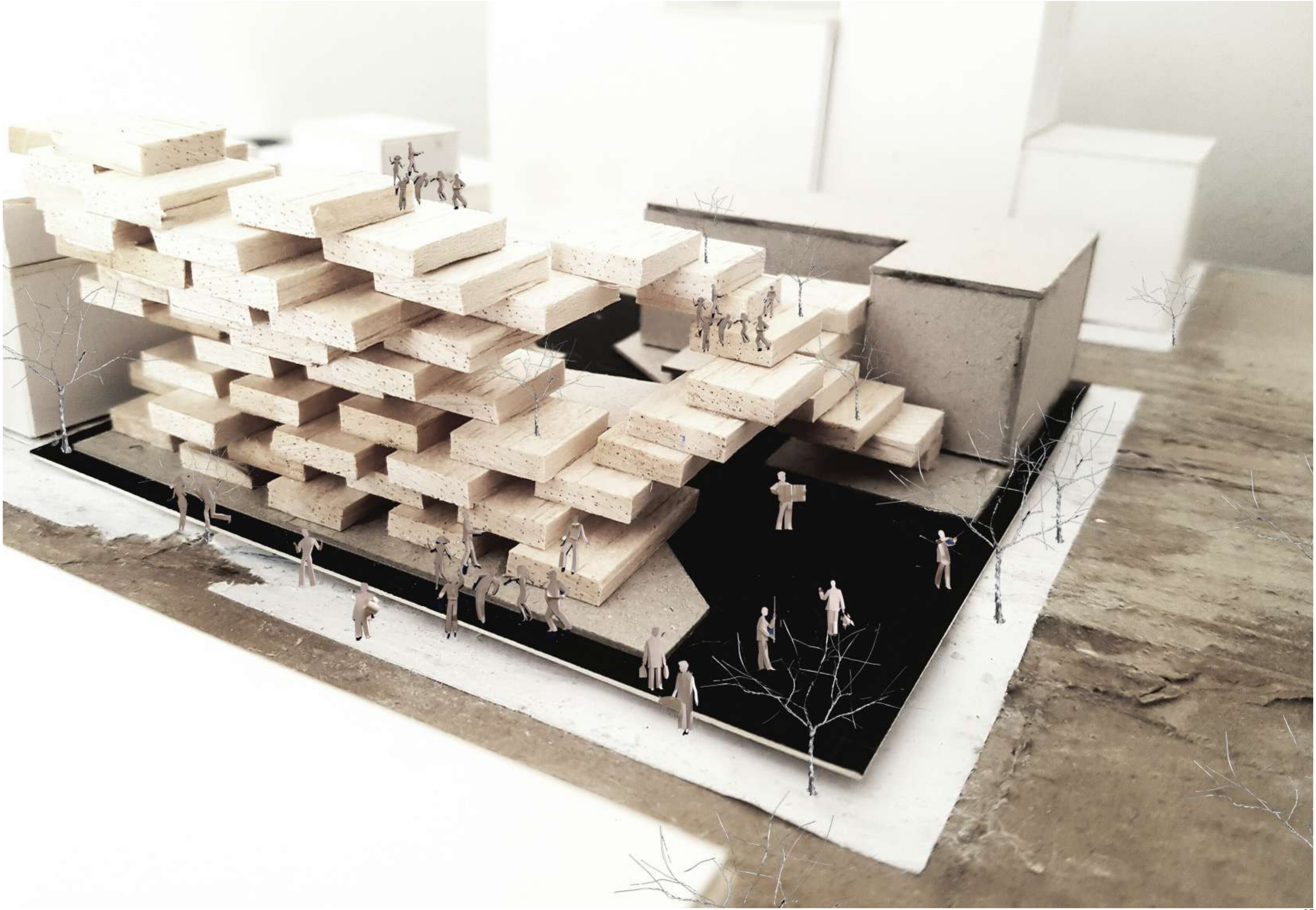


Fig 4.2(ii): *Design Charrette Iteration 1, Experimenting with Modular blocks and Wood for Materiality "View from Juta st (South)", (Author 2020).*


Fig 4.2(iii): *Design Charrette Iteration 1, “View from De korte st (South)”, (Author 2020).*

Fig 4.2(iv): *Design Charrette Iteration 2, Experimenting with Steel Modules "View from Juta st (South)", (Author 2020).*

Fig 4.2(iv): *Design Charrette Iteration 3,The Roof as a Functional Landscape "View from De korte st (North)", (Author 2020).*

Fig 4.2(v): *Design Charrette Iteration 3,The Roof as a Playful Landscape "View from Juta st (South)", (Author 2020).*

Fig 4.2(vi): *Design Charrette Iteration 4, Experimenting with Structure "View from Juta st (South)", (Author 2020).*

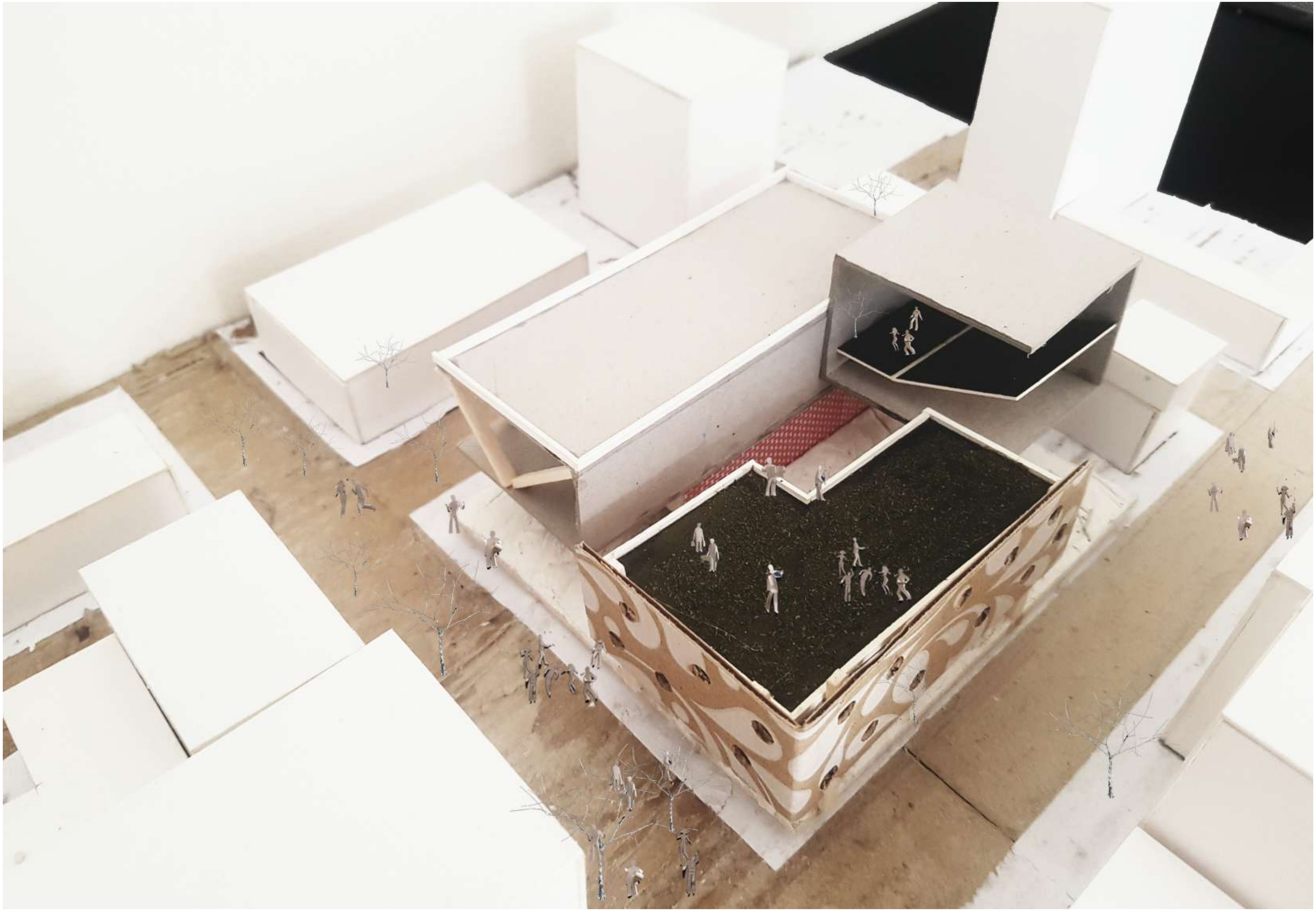


Fig 4.2(vi): *Design Charrette Iteration 4, Experimenting with Building Skin "View from De korte st (South)", (Author 2020).*

Chapter 5
Precedent Studies.

SYNOPSIS

In this chapter, intuitive and responsive design concepts will be scrutinised through detailed analysis of built architectural projects. Diagrams that break down complex ideas are going to be the primary tool used to understand how concepts are realised as built form. A local and international precedent are chosen to give both a good understanding of scope and context. Most importantly, the precedent studies will rationalise some of the more intuitive concepts of the previous chapter into specific and clear design principles and strategy.

PRECEDENT STUDY.

Copenhill Clean Energy Factory .

Architect	BIG
Date of Completion	2017
Location	Copenhagen
Typology	Factory

PROJECT SUMMARY

The project is a radical rebuff of convention and typology as it completely redefines what a factory is and what it could be. The brief re-imagines a productive space as playful by incorporating a ski slope on the roof of a traditional factory. The architecture introduces a civic interface which is engaging and activates the space around the building. The notion of using a roof landscape as a playful element on which civic program can be introduced is captivating and is going to be applied to the design proposal.

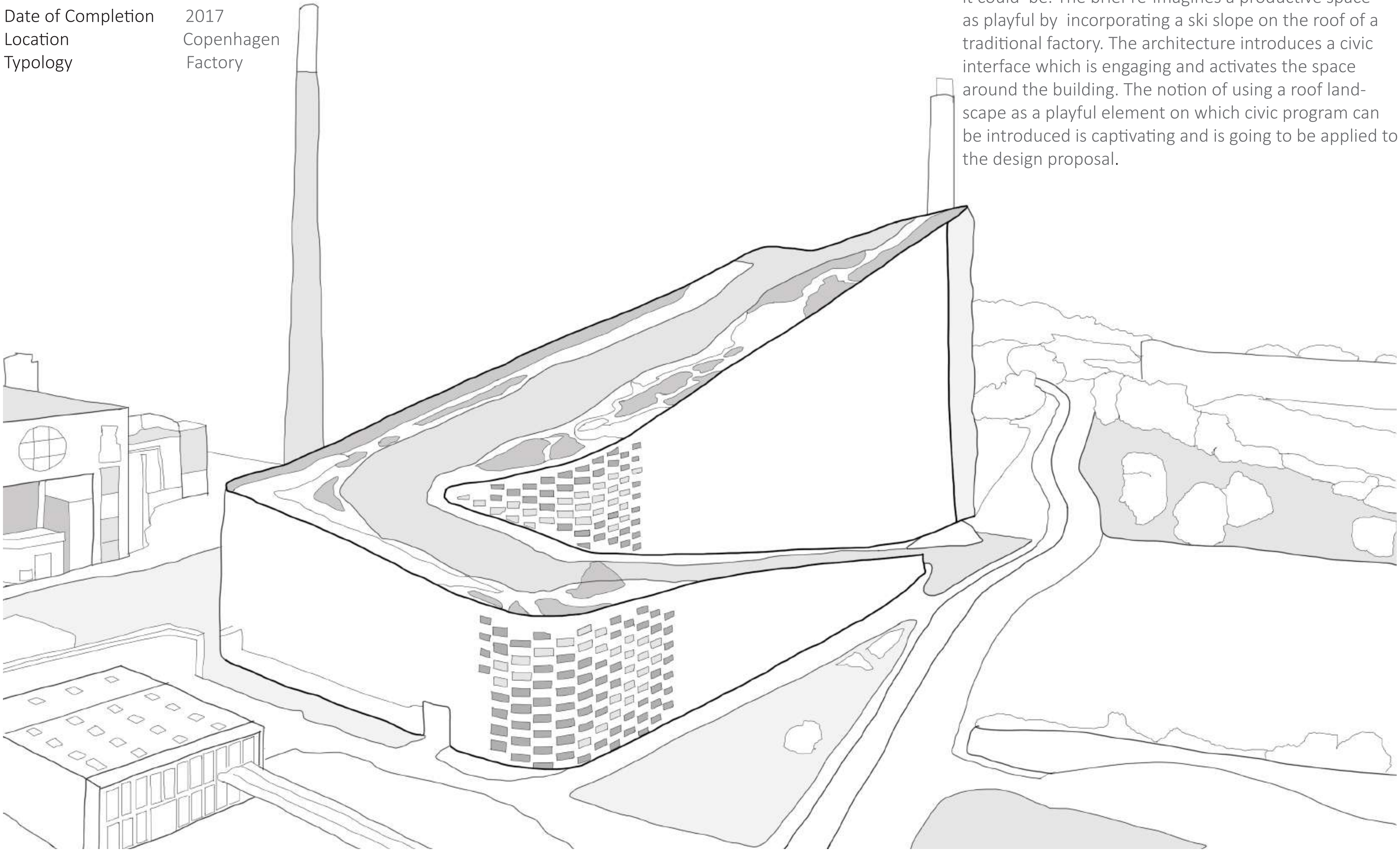


Fig 5.1(i): *Drawing of Copen Hill Waste to Energy Power Plant by BIG Architects, Copenhagen (Author 2020).*

Copenhill Factory Conceptual Exploration.

PRECEDENT ANALYSIS (Diagram 1)

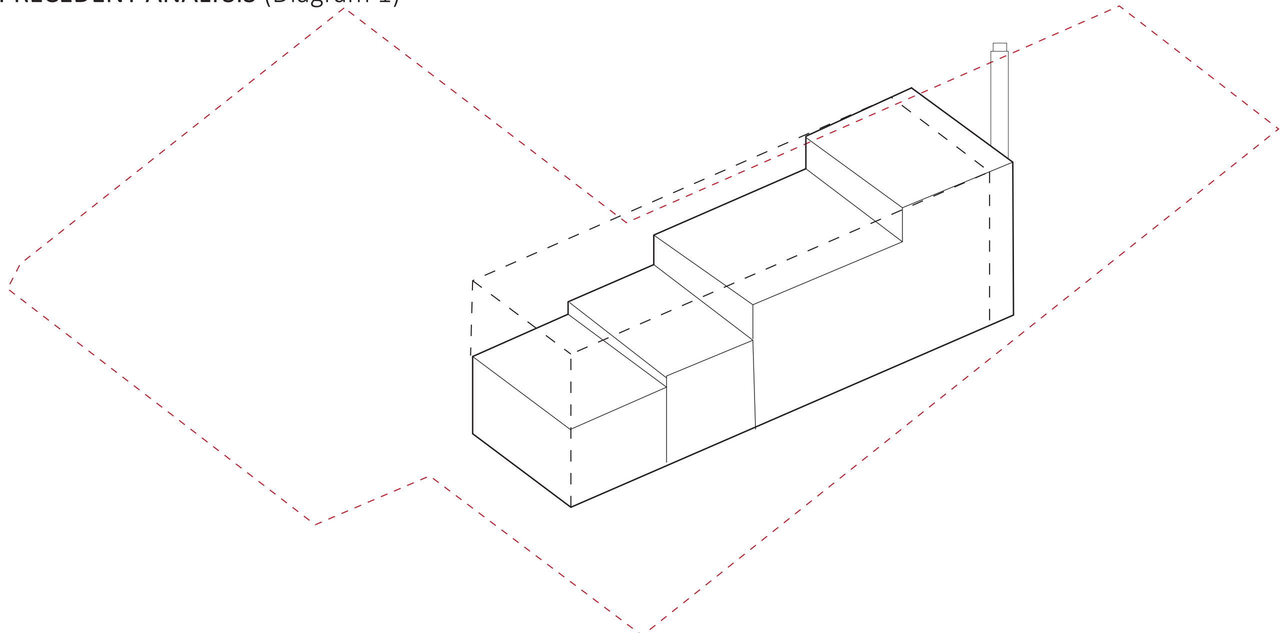


Fig 5.1(ii): *Diagram of Typical Factory Typology, BIG Architects (Author 2020).*

PRECEDENT ANALYSIS (Diagram 1)

Fig 5.1(ii) shows how the design of the factory initially incorporated the functional needs of the space with open clear volumes and extremely generous floor to ceiling heights. The basic requirements such as natural light, ventilation and adaptable space where met in the initial stages of the design. This design strategy is going to be applied in the "Digital Manufacturing Factory"proposed by the author in this discourse. It can be observed from the precedent that by meeting the functional brief and requirements first, room for exploration and experimentation is freed up.

PRECEDENT ANALYSIS (Diagram 2)

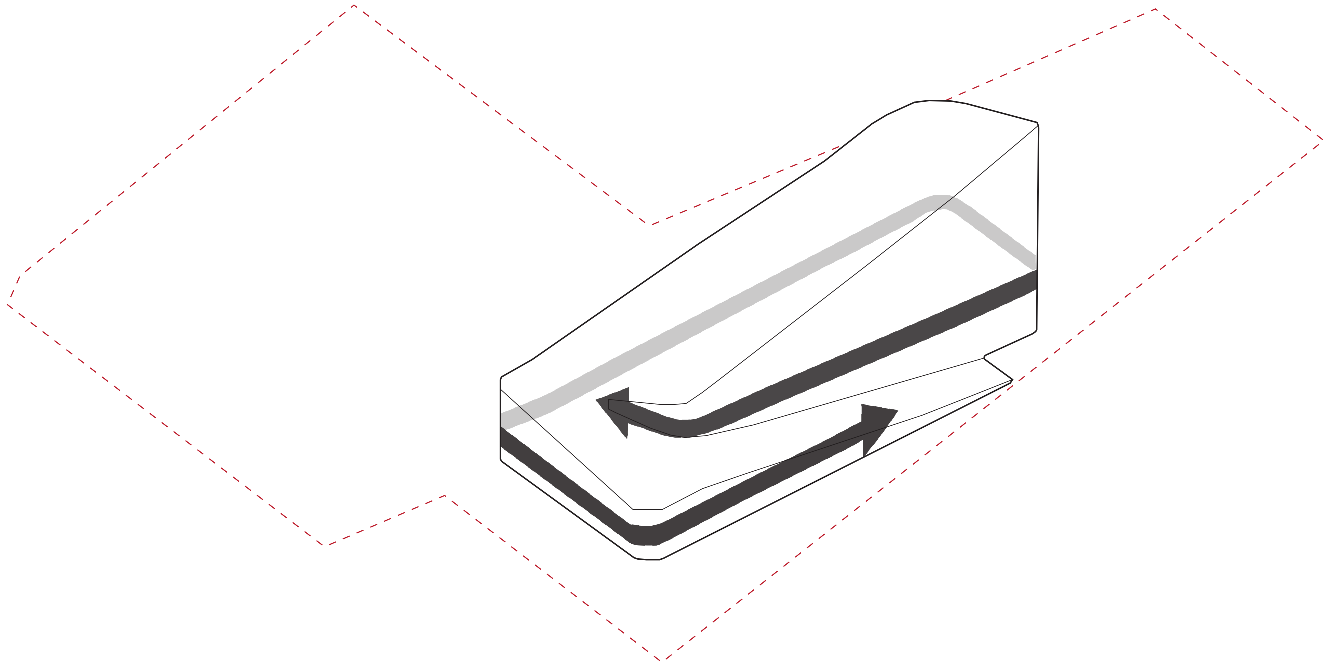


Fig 5.1(iii): *Diagram of Reimagined Factory Typology , "Functional Facade." BIG Architects, Copenhagen (Author 2020).*

PRECEDENT ANALYSIS (Diagram 2)

Fig 5.1(iii) illustrates the transformation of the design from typical factory to an interesting organic form with a usable fifth facade. The architects also saw the facade as an opportunity to make the building more interactive by using aluminum blocks and planters to make the building aesthetically more appealing and sustainable. The author intends to use the building facade as an element that is both visually appealing and simultaneously enhances the overall building performance.

Copenhill Factory Conceptual Exploration.

PRECEDENT ANALYSIS (Diagram 3)

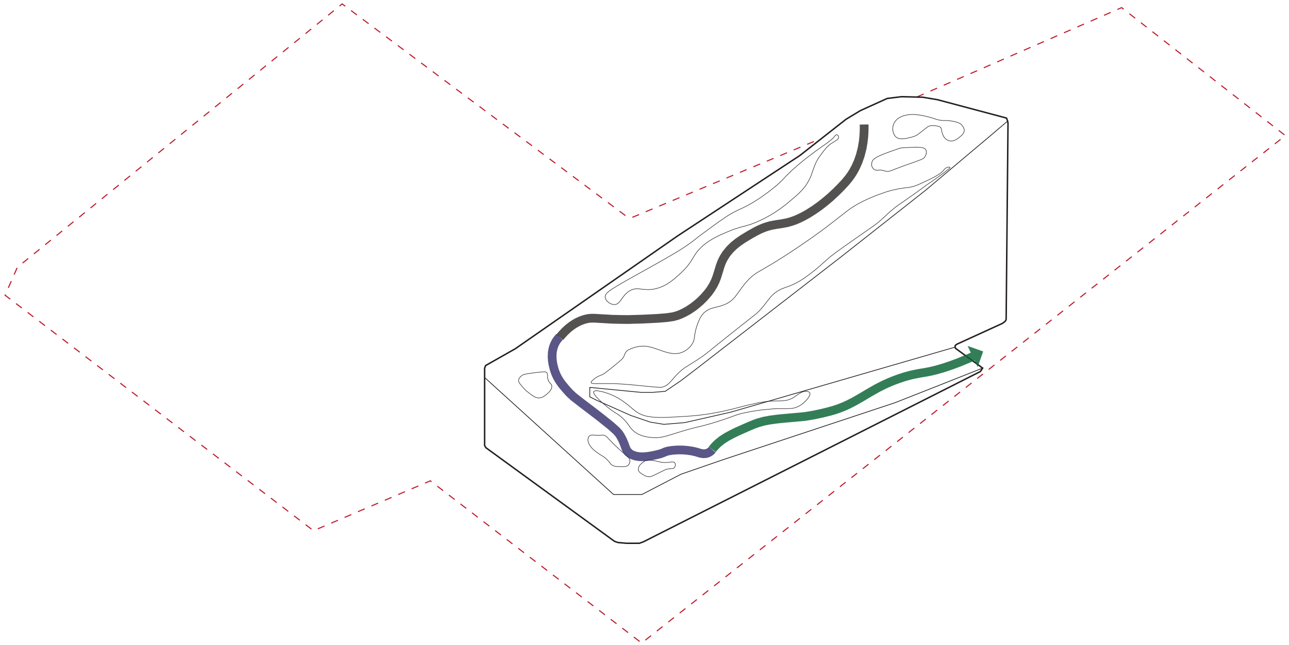


Fig 5.1(iv): *Diagram of a Playful Factory Landscape BIG Architects, Copenhagen (Author 2020).*

PRECEDENT ANALYSIS (Diagram 3)

Fig 5.1(iv) shows the extension of the landscape from the ground to the sky. The architecture touches both the sky and ground in an interactive and playful manner. The same is envisioned for the Digital Manufacturing factory in Braamfontein. Is it possible to imagine a factory that is light, driven by precision and touches the sky and groundfloor very delicately? These are some of the design questions that are going to be explored in this discourse.

PRECEDENT ANALYSIS (Diagram 4)

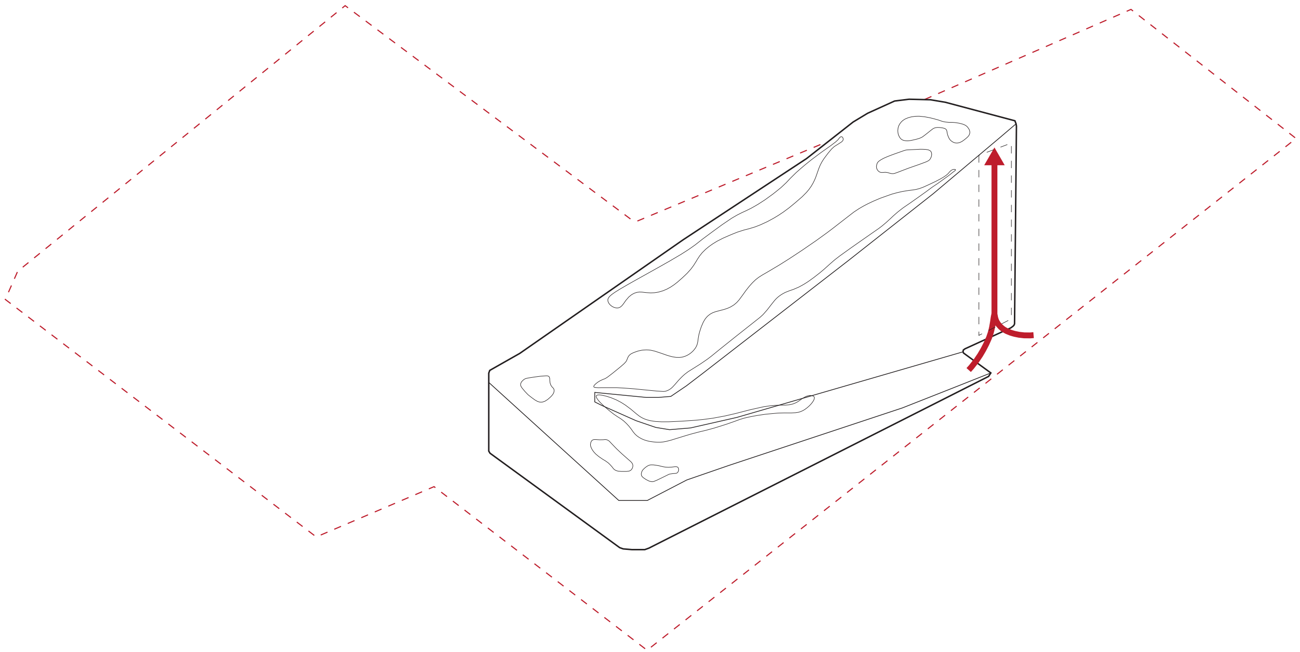


Fig 5.1(v): *Diagram of an Interactive Edge BIG Architects, Copenhagen (Author 2020).*

PRECEDENT ANALYSIS (Diagram 4)

Fig 5.1(v) illustrates how the building skin can take on multiple roles. In this case a climbing wall is added to allow a direct link between ground and top of the building. In this way the architecture becomes an extension of public usable space as well as functional. This duality of roles (functional and playful) is another of the design strategies that is going to be adopted in the design proposal.

PRECEDENT STUDY.
Tshimologong Precinct .

Architect	GWA
Date of Completion	2016
Location	Braamfontein
Typology	Innovation Centre

PROJECT SUMMARY

Tshimologong is an insightful and ambitious architectural experiment that is driven by technology, innovation and creativity. How does one design a space that encourages creativity and experimentation? The designers center the spatial design around lucid public space at different scales. This strategy allows the more rigorous and traditional productive spaces to develop around these collision spaces which are meant to foster exchange.

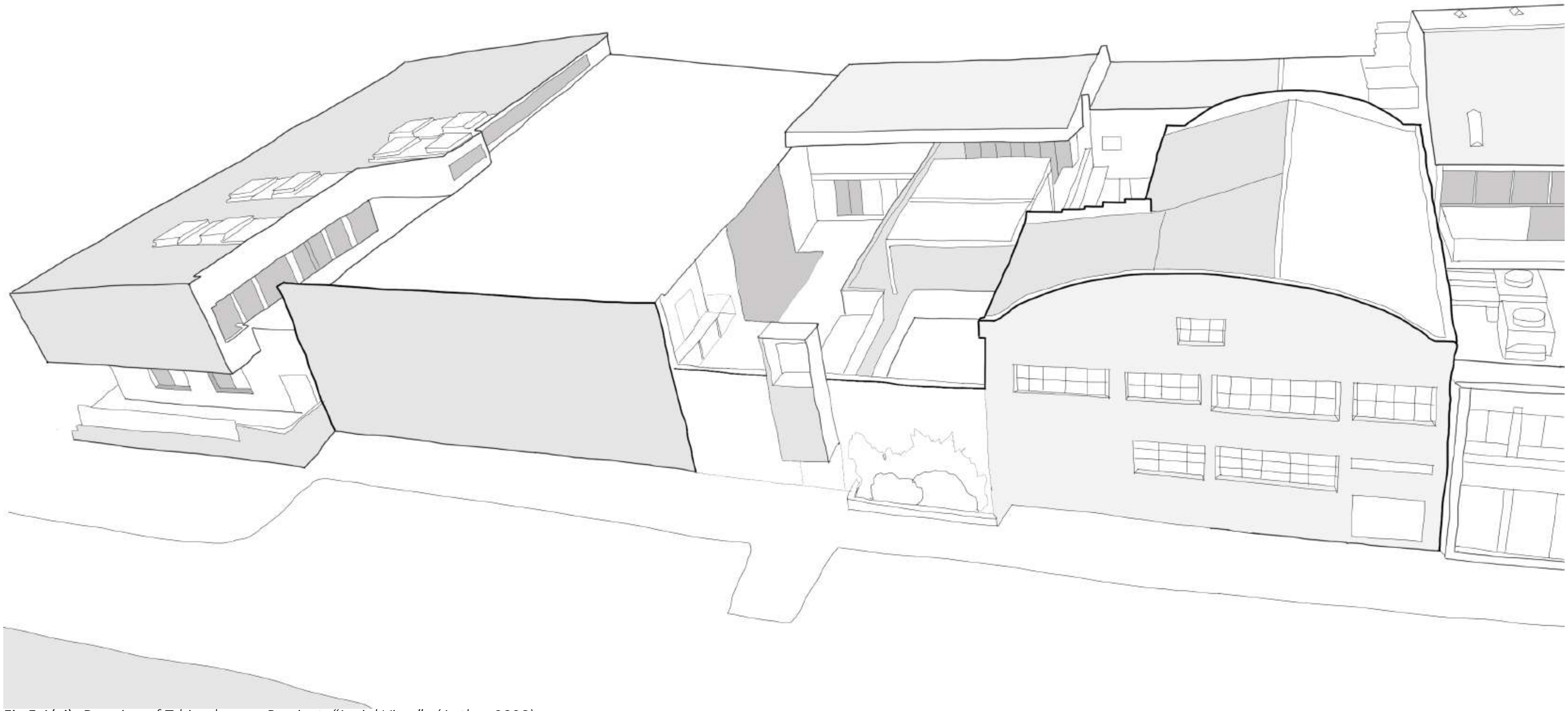


Fig 5.1(vi): *Drawing of Tshimologong Precinct, "Aerial View"   (Author 2020).*

Tshimologong Precinct Planning.

PRECEDENT ANALYSIS (First Floor)

The first floor is mostly comprised of private offices and specific industry related program. The change in levels is thus used as a control mechanism to move from public and open ground-floor to the more controlled and restricted first floor. However the spatial planning on the first floor is also centered around generous, highly adaptable public spaces, refer to **Fig 5.1(viii)**. The skillful use of ,change in levels, as a method of defining access, is one of the fundamental strategies that is going to be applied to the author's design proposal.

PRECEDENT ANALYSIS (Ground Floor)

In sharp contrast to the first floor the ground-floor is much more legible and accessible. This is reflected in the higher density of users one finds on the afore mentioned. The pockets of public space lure activity that creates vibrant and engaging environments. It is these loosely defined spatial attributes of the architecture that foster the exchange and collaboration vital for innovation. The same principle is going to be applied in the proposed "Digital Manufacturing Factory", where smaller pockets of public and co-working spaces will form the core of the spatial layout.

Fig 5.1(vii): *Diagramatic Plans of Tshimologong Precinct, Showing Space Layout & Access (Author 2020).*

Tshimologong Axonometric Drawing.

PRECEDENT ANALYSIS (Axonometric)

Fig 5.1(viii): Shows the relationship between the public, private and in-between spaces. It highlights the essence of recreational spaces in a productive environment. How does one design recreational space in an intense productive environment? This is one of the questions the design proposal will attempt to resolve.

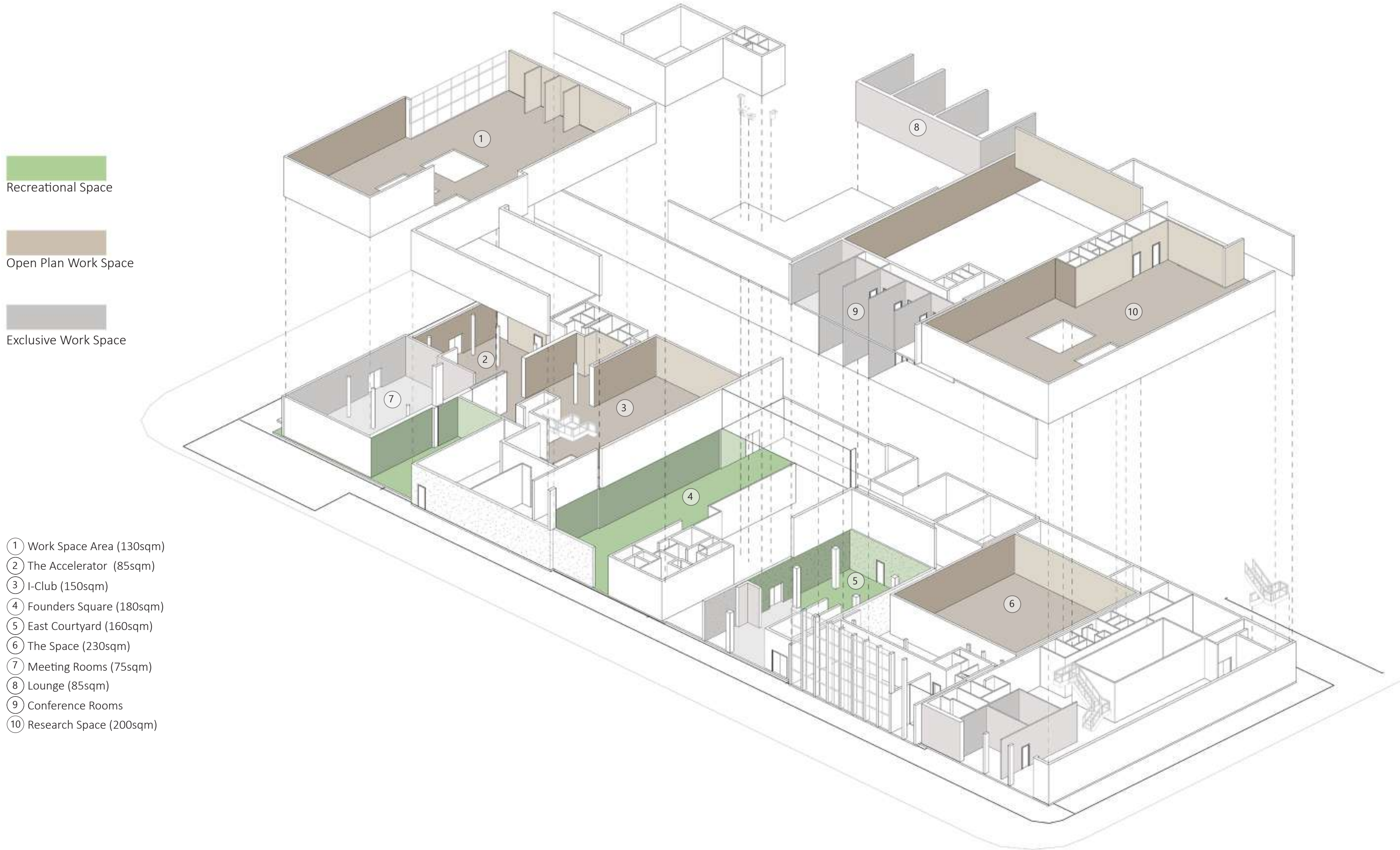
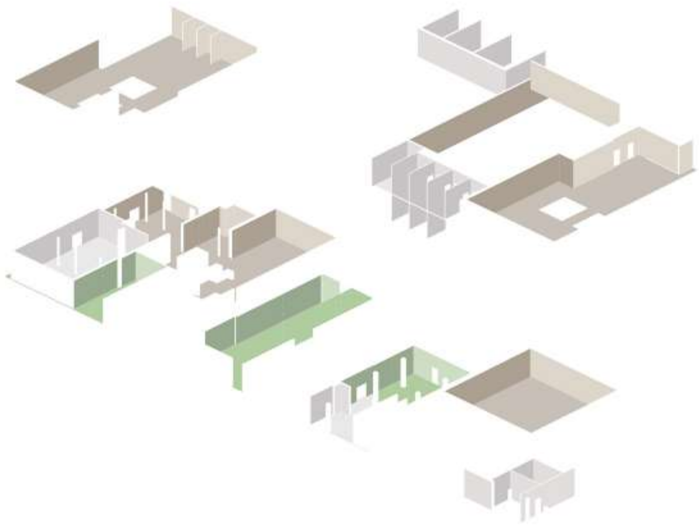


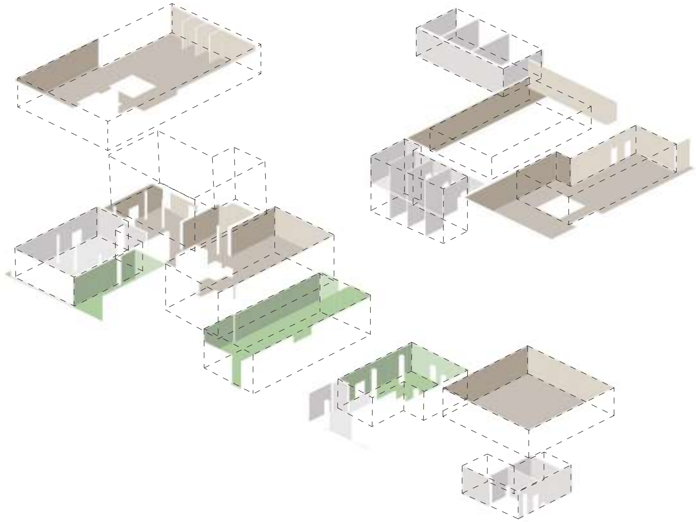
Fig 5.1(viii): *Axonometric Drawing of Tshimologong Precinct, illustrating Relationships between Spaces (Author 2020).*

Tshimologong Analytical Diagrams.

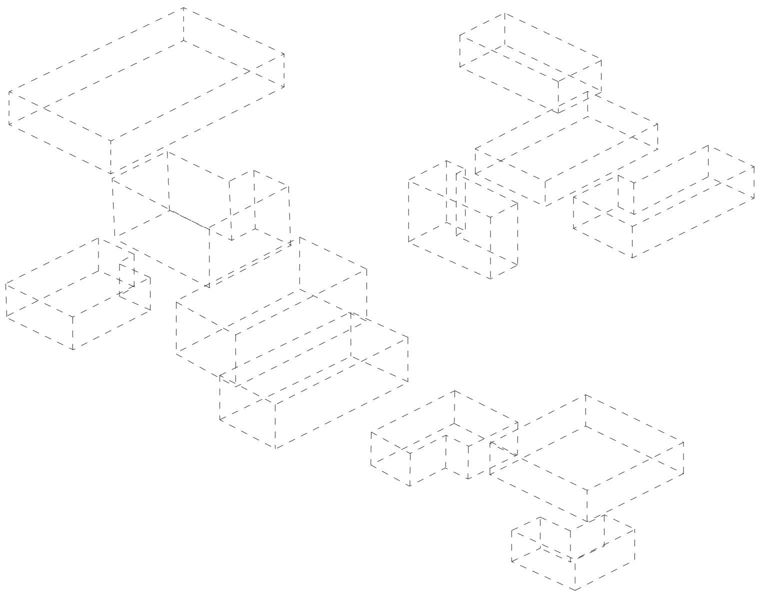
Ⓐ (Diagram 1) What is the feeling and volume of the Spaces?



Ⓑ (Diagram 2) What are the basic geometries that form the space?



Ⓒ (Diagram 3) How are these geometries put together?



Ⓓ (Diagram 4) How are the geometries connected "circulation"?

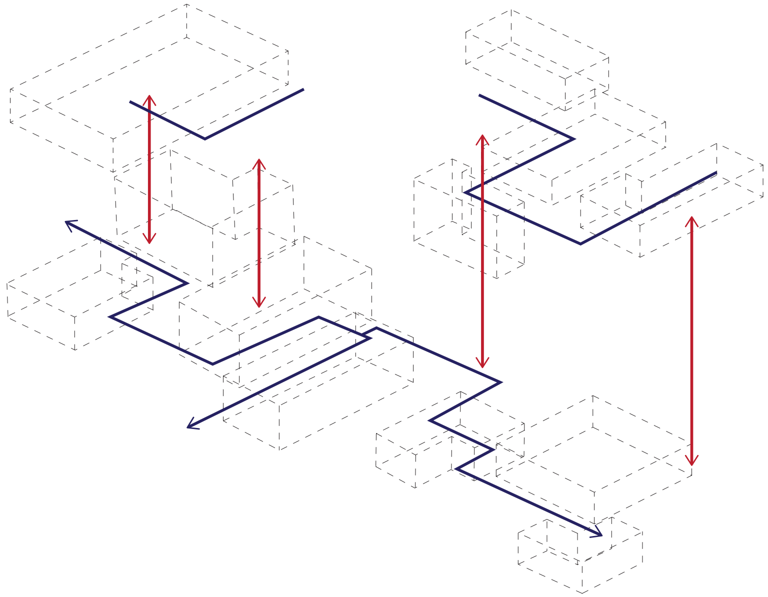


Fig 5.1(ix): *Series of Axonometric Drawings illustrating Basic Geometric Design of Tshimologong. (Author 2020).*

Chapter 6
Design Brief.

SYNOPSIS

This chapter is a culmination of all the preceding chapters findings, discussions and conclusions. The spatial program and layout of the building are highlighted in this chapter. Here the main conceptual approach to space development and hierarchy of function is clearly outlined. The feasibility of the program and its relationship to the context is also discussed and lastly the spatial vision of the design intervention is communicated.

6.1 Design Brief

This discussion serves to define and delineate the program and function that will form the Digital Manufacturing Factory. As has been discussed in one of the previous chapters of this discourse (Democratisation of Making), there is a revolutionary phenomenon that will significantly change the way goods and services are made and supplied (digital manufacturing). This newly found freedom has the potential to empower and emancipate the lesser developed economies and underfunded entrepreneur who faces rigid capital barriers from entering the “makers space”, where ideas can be translated into products and businesses.

How then can architecture be involved in the process of value creation and disruption by leveraging current trends? Hence forth this discourse argues that by combining untapped human capital (knowledge) and expertise. Infrastructure in the form of built architecture has the potential to foster and enable a new form of creativity and experimentation that will manifest in the form of physical prototypes, (commercially exploitable).

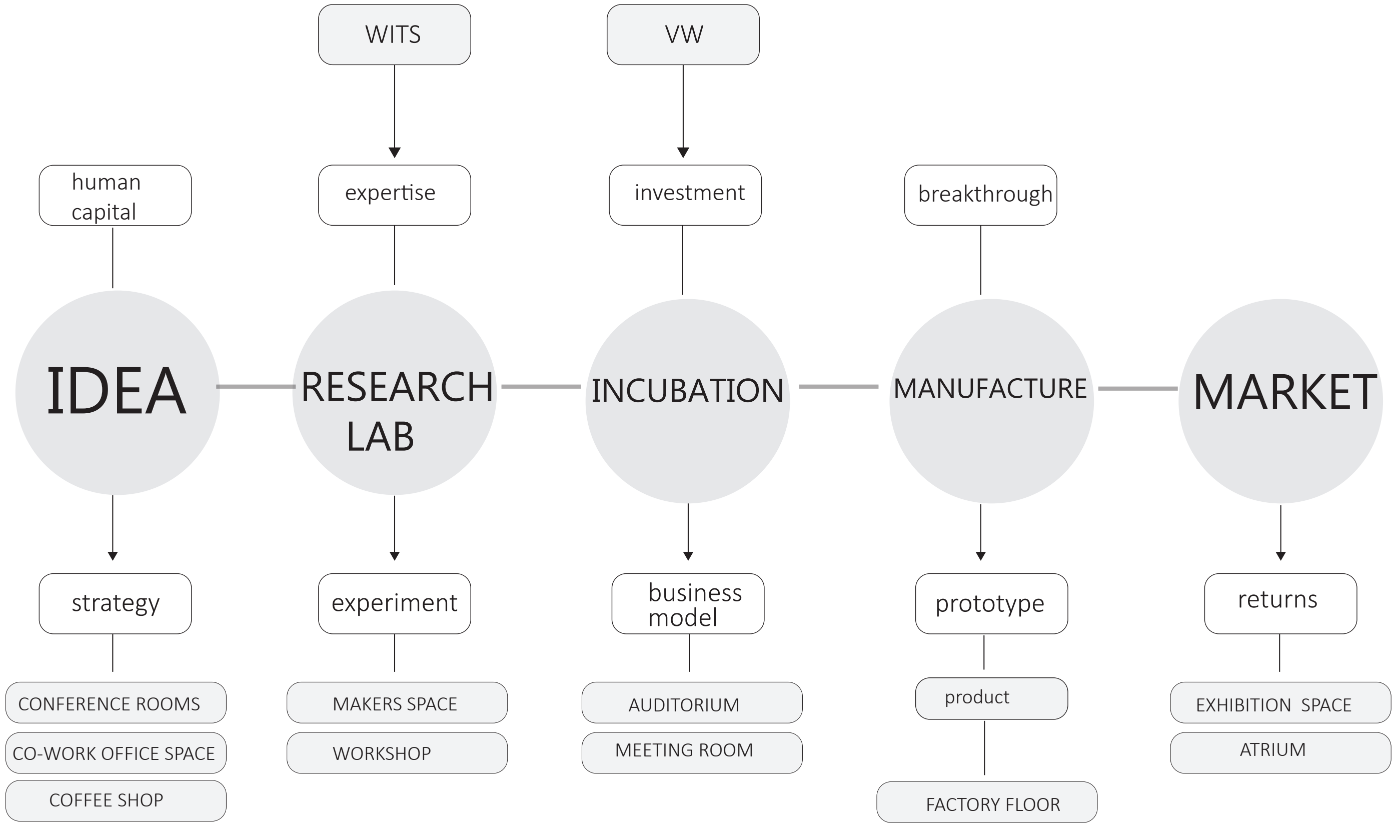


Fig 6.1(i): *Diagram Explaining Digital Manufacturing Program & Function. (Author 2020).*

As discussed in previous chapters, dense and diverse neighborhoods foster enormous creative potential. This fact makes Braamfontein a suitable testing ground for this experiment largely depended on a closely integrated network between capital, process and output, refer to Fig 6.1(i). Human capital in the form of knowledgeable and highly skilled young individuals will be the primary facet required for the “Digital Manufacturing Factory.” This will proliferate in the form of entrepreneurs with ideas, willing to explore and experiment. The collaborative component of the program will form the essence of the architectural spatial planning, with the careful design of collusion space that is less formal public space and highly adaptable, as is the case with Tshimologong.

How does this new experimental program embed itself into the existing established social and physical infrastructure such as Wits University and the existing owners of site VW?

Perhaps the strength of disruption and innovation of the “Digital Factory” lies in its ability to actively engage separate entities and allow networking and cross pollination of ideologies in ways previously not possible. What if Wits university provides the program with research resources and expertise and VW invest in the more successful experiments and business models? In that way the entrepreneur (skilled youth), academic (Wits) and capitalist (VW) all collaborate in the creation of a new typology.

How does the Program Work?

The sequence diagram illustrates the exchange and collaboration which forms the core essence of the proposed program. The system is largely based on knowledge, skill, creativity and technology. What kind of architecture can bring this idealistic vision to life?

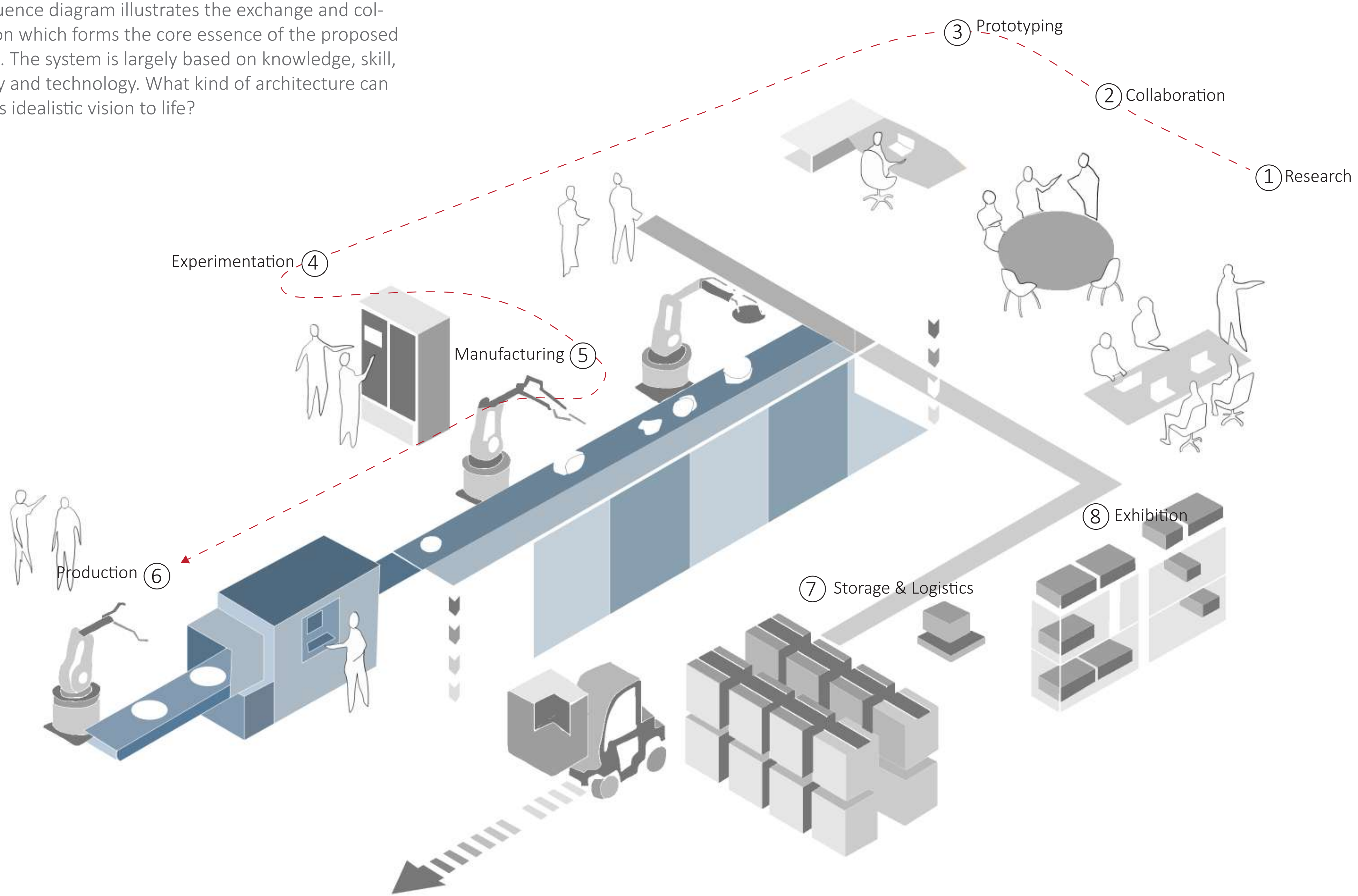


Fig 6.1(ii): *Sequence Diagram illustrating Program & Function. (Author 2020).*

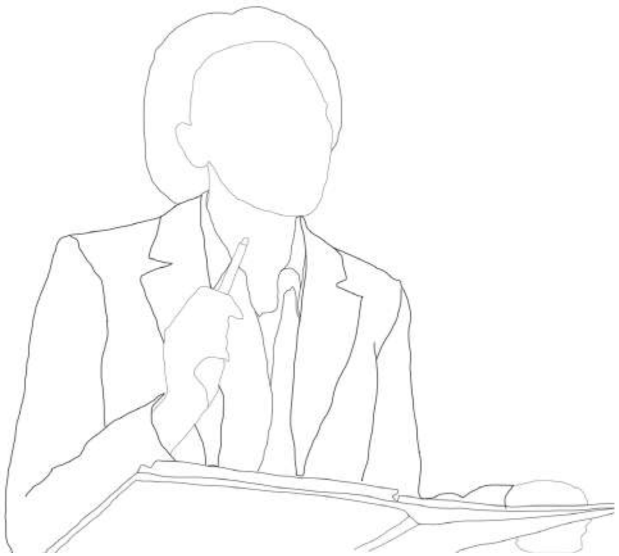
Program Reimagined ?

What if a functional program was layered with playful public space that brings a civic interface and opens up the building? The public interface could take the form of a central atrium space that is an exhibition space.

Fig 6.1(iii): *Sequence Diagram illustrating Program & Function. (Author 2020).*

How Does the Collusion Space Work ?

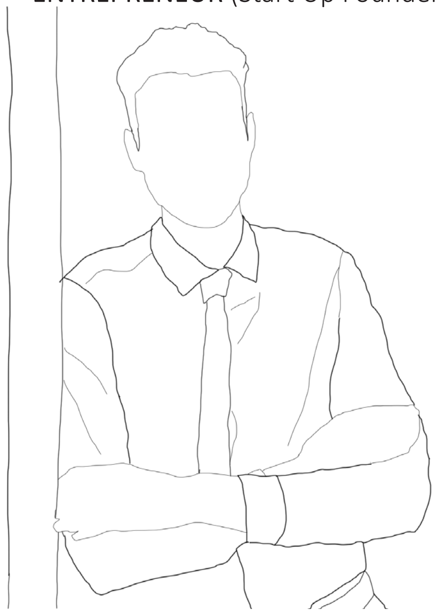
STUDENT (Wits University)



SCENERIO

Karabo is 4th year student from Wits University studying Mechanical Engineering. For her dissertation she is researching how to make an autonomous, self driving taxi. She hears about the great coffee sold on the ground-floor of the Digital Manufacturing Factory and on her break decides to go check it out. In the atrium she runs into an exhibition that is showcasing various prototypes. It is here were she runs into Melusi who just finished setting up his “virtual robotic arm” for display. Melusi’s exhibition is not getting any attention, so he is enthusiastically waiting to chat to anyone who shows the slightest interest. This is how the two meet and speak about their ideas.

ENTREPRENEUR (Start Up Founder)



SCENERIO

Melusi is a 28 year old founder of TYT Robotics. He founded his own company a year earlier after he was retrenched from South African Airways where he worked as a technician. He was taken as an apprentice at SA Airways soon after matric so he has no qualification but is extremely passionate about making things and as soon as he heard about the Digital Manufacturing Factory he rented a desk on the second-floor Co-working space and has been using the Workshop and Fabrication Lab to make his robotic arm prototypes. However, no one has bought into his ideas yet so he keeps setting up his work in the atrium at exhibitions. The previous week he had run into Chris, who had stumbled into his work, and had promised to come view his exhibition but had never returned. So Melusi is having a chat with Karabo when Chris finally shows up to engage the two.

INVESTOR (Director Earnest & Young)

Fig 6.1(iii):

SCENERIO

Chris is a business executive at one of the biggest consulting firms in the country. To him time is money, and he staunchly believes in hard work. Whilst having a meeting at Liberty a few streets away from the Digital Manufacturing Factory in Braamfontein load shedding happens and the meeting has to be reconvened somewhere. Chris’ s colleague mentions the “Roof top garden pavilion” at the Digital Manufacturing Factory where there is good natural light, ventilation and greenery. Chris reluctantly agrees and on his way to the rooftop he stumbles into Melusi and finds his story inspiring. After the next meeting at Liberty, Chris renumbers Melusi and decides to go have another look at his work, here he meets Melusi together with Karabo. The three have coffee and discuss business viability, design shortfalls and potential investment.

Fig 6.1(iv): *Illustrated Scenerio of Collusion Space Works. (Author 2020).*

SPATIAL LAYOUT
Civic Interface & Program

As has been argued earlier in this chapter "digital manufacturing" is a product of an intricate system of networks and relationships. From this point of view it can be argued that perhaps the main focus of a "Digital Manufacturing Factory", is not actually the production of prototypes and making of objects but rather the creation and development of ideas which form the core of the disruptive technology.

Given the above argument, creativity and collaboration are the primary components on which the program is built upon. As with the case with Tshimologong, discussed in the previous chapter, the more formal rigid functions of the program such as, research, fabrication studio and manufacturing need to attach to a highly adaptable civic central stronghold (collusion space) that holds the whole scheme together. With that in mind, there is a clear hierarchy in the prominence of spaces and the Atrium plays the role of a spatial anchor and linchpin, on which adjacent building functions attach, refer to **Fig 6.1(iv)**.

Equally important is the edges and threshold which actively engage the street and the larger pedestrian and vehicular traffic. The author envisions a porous thoroughfare on ground floor where there is visual stimulation on the building edge (facade) through playful program such as a coffee shop, and exhibition space that spills out into the street and proposed "public square", discussed in detail in the next chapter.

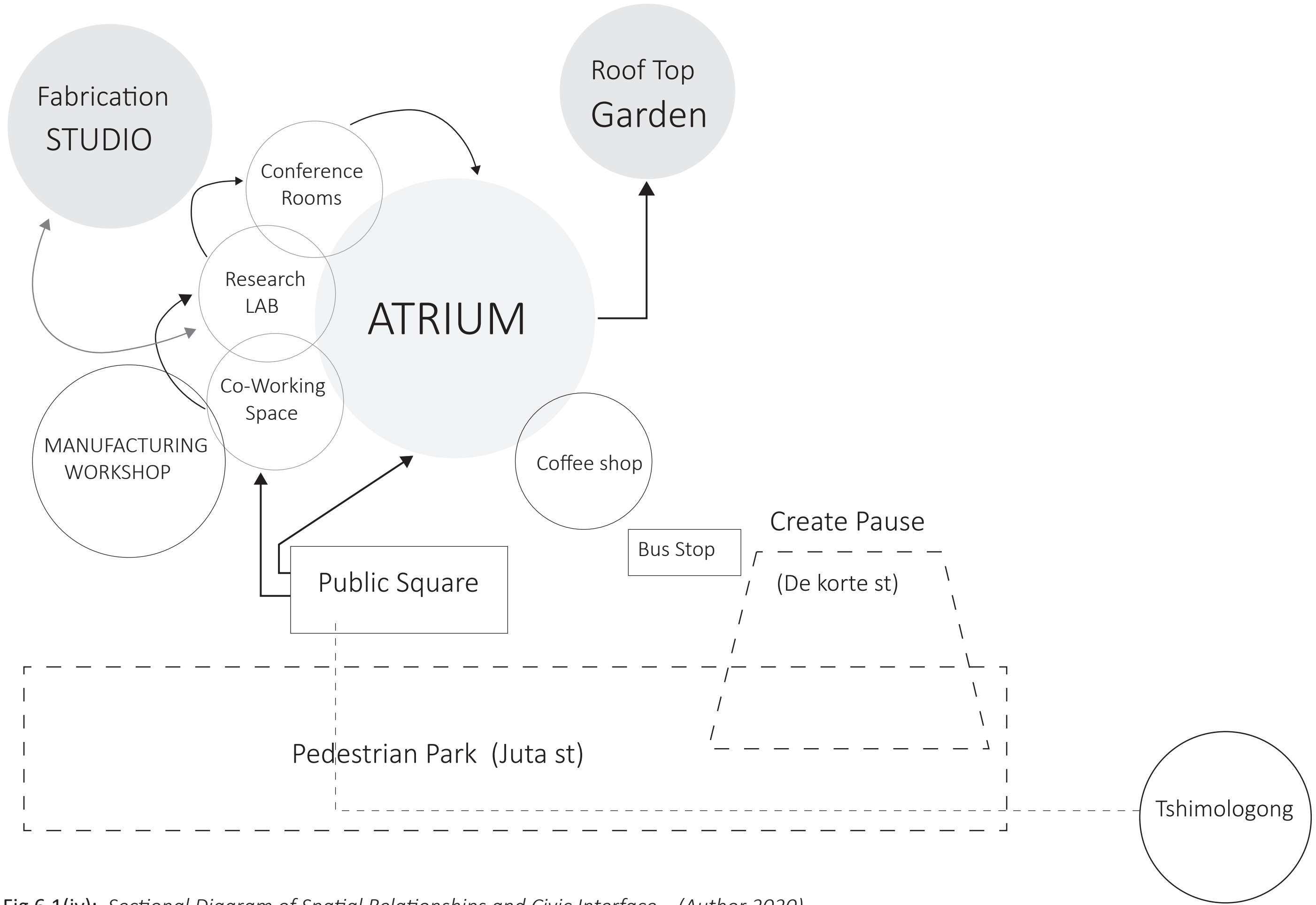


Fig 6.1(iv): *Sectional Diagram of Spatial Relationships and Civic Interface . (Author 2020).*

The author argues that a new building proposal located in Braamfontein needs to be ingrained in the social fabric of the area. This entails that the building has to be a civic installation as well as have a productive function. This duality of roles is a design strategy discussed in the previous chapter, and executed by BIG Architects in the design of Copenhill Factory. Put in context the design proposal is going to have a usable roof top garden to compliment the atrium. This layering of civic and public space will ensure a variety of desirable spaces, that will ideally attract a diverse crowd.

Ideally the building program will contextually interact with available resources by tapping into the research and expertise of Wits University and Tshimologong. By deliberately placing a creative, innovative program "Digital Manufacturing Factory" next to an already existing one "Tshimologong", this will increase the chances of knowledge spillovers and spontaneous encounters and exchange. This sort of relationship will theoretically increase collaboration and competition resulting in a greater innovative energy and output.

Artist Impression of Atrium (Collusion Space)

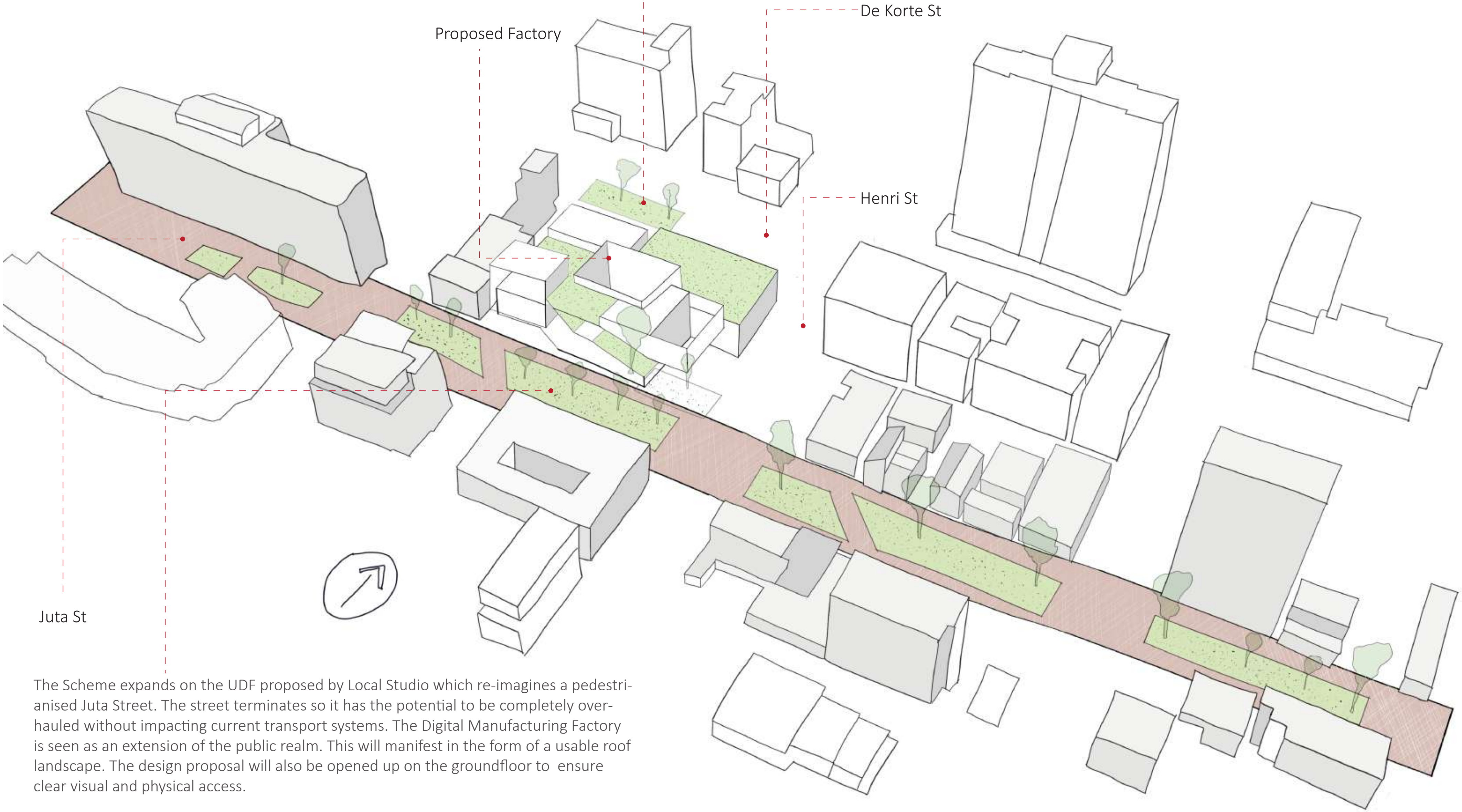
Fig 6.1(v): *Collage of Central Atrium (Collusion Space), Exhibitions and Events will be hosted in the Space, (Author 2020).*

Chapter 7
Design Strategy.

SYNOPSIS

This chapter outlines the main design principles and guidelines that govern the development of form and space. Particular attention is paid to the prominence of public space and its significance in the Braamfontein context. An Urban Design approach is juxtaposed to internal spatial planning as a method of creating seem-less interaction between the two. A sketch design, is proposed at the end of the chapter as a means of further developing the design process to the next levelof detail and layout.

The treatment of De Korte St Edge is particularly important. The street is a major transit node out of the city and forms a vital linkage avenue. How then does the design proposal engage such a vital piece of infrastructure. The author proposes that the building cuts back to create a moment of pause and observation. This will allow the continuous flow of fast moving traffic at the same time cater fro the pedestrian and human scale.

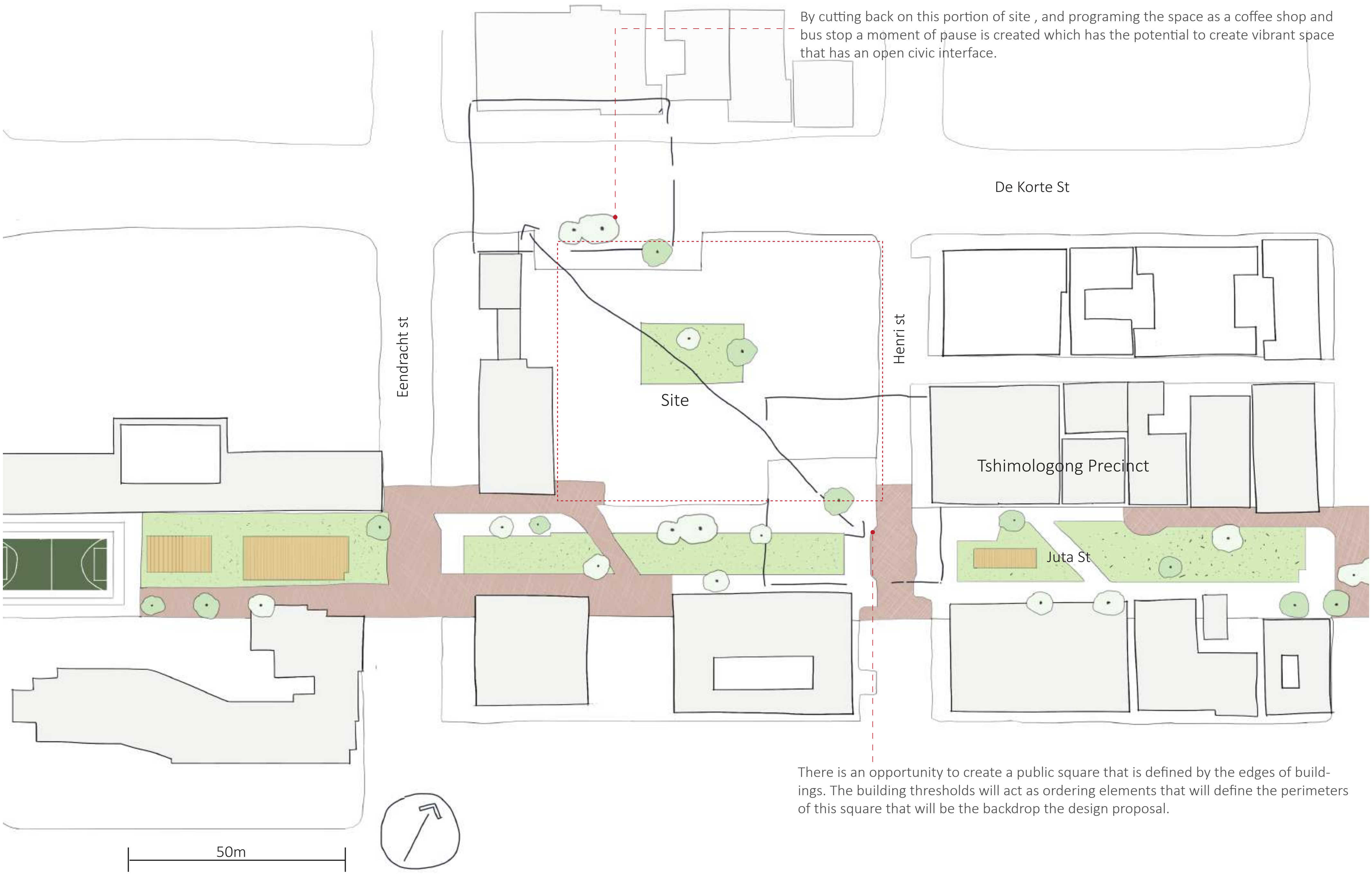


The Scheme expands on the UDF proposed by Local Studio which re-imagines a pedestrianised Juta Street. The street terminates so it has the potential to be completely overhauled without impacting current transport systems. The Digital Manufacturing Factory is seen as an extension of the public realm. This will manifest in the form of a usable roof landscape. The design proposal will also be opened up on the groundfloor to ensure clear visual and physical access.

Fig 7.1(i): *UDF of Braamfontein West, Proposed by Local Studio 2016 , Redeveloped by (Author 2020).*

Urban Design Strategy

By cutting back on this portion of site , and programing the space as a coffee shop and bus stop a moment of pause is created which has the potential to create vibrant space that has an open civic interface.



There is an opportunity to create a public square that is defined by the edges of buildings. The building thresholds will act as ordering elements that will define the perimeters of this square that will be the backdrop the design proposal.

Fig 7.1(ii): *Plan of Braamfontein West UDF, 2016 , (Author 2020).*

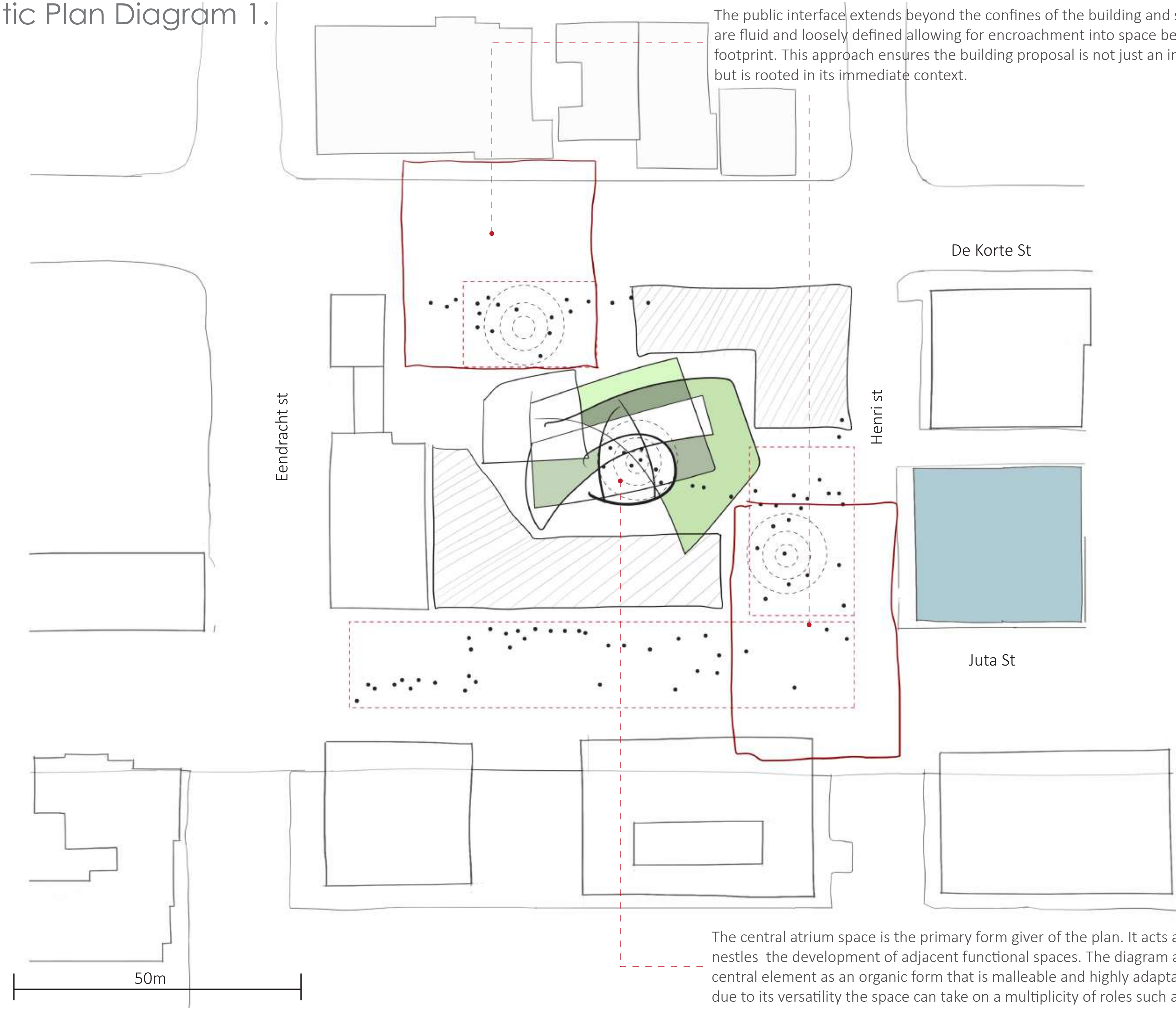
Factory as an extension of the Landscape.

The drawing is a conceptual exploration playing with the notion of the Digital Manufacturing Factory being an augmentation of the civic landscape. The drawing illustrates how architectural elements such as the building envelope and roof can become an extension of usable space.

Fig 7.1(iii): *Conceptual Exploration of Relationship between Landscape and Proposed Factory, (Author 2020).*

Schematic Plan Diagram 1.

The public interface extends beyond the confines of the building and site. The thresholds are fluid and loosely defined allowing for encroachment into space beyond the building footprint. This approach ensures the building proposal is not just an installation onto site but is rooted in its immediate context.

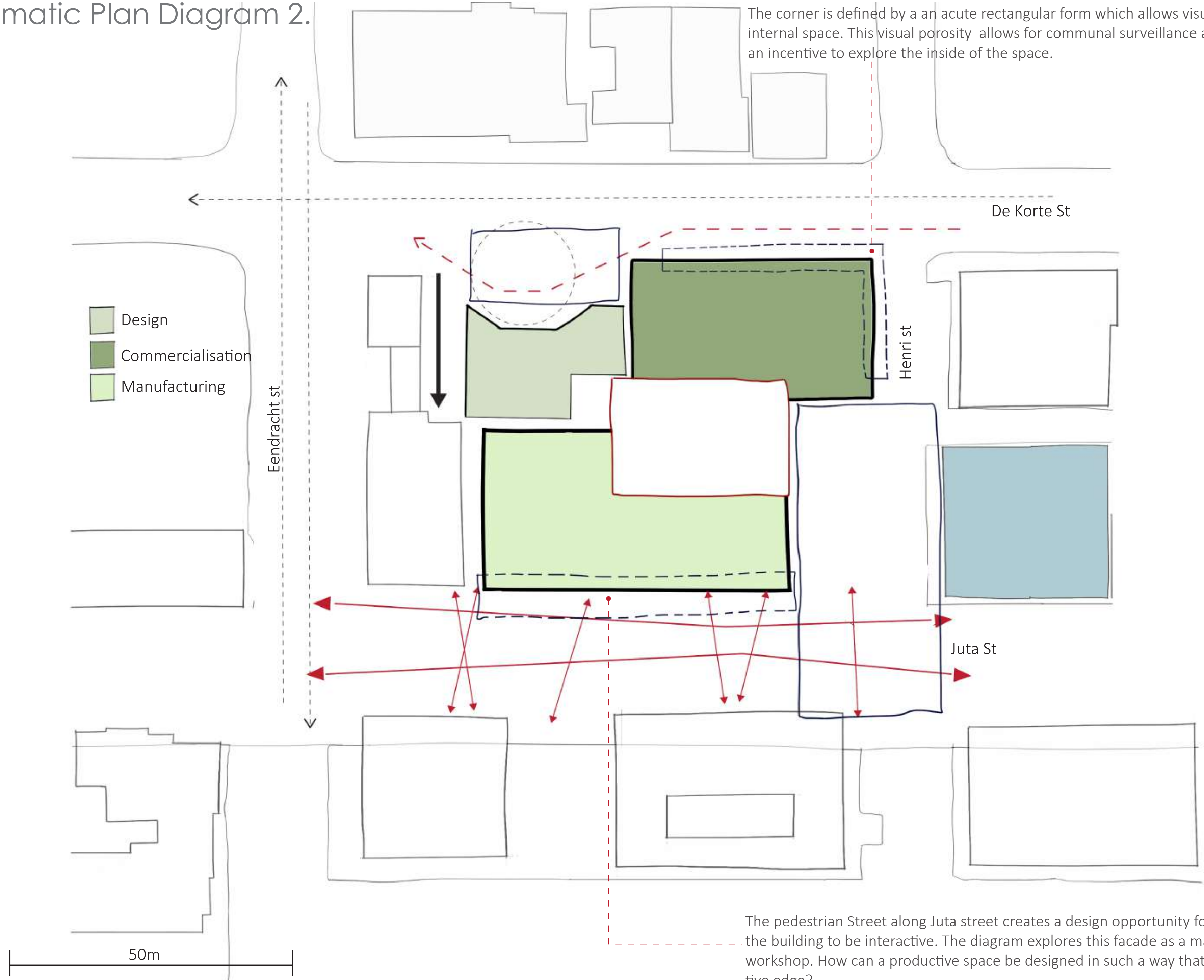


The central atrium space is the primary form giver of the plan. It acts as anchor which nestles the development of adjacent functional spaces. The diagram also explores this central element as an organic form that is malleable and highly adaptable. Resultantly, due to its versatility the space can take on a multiplicity of roles such as hosting events,

Fig 7.1(iv): *Diagram of Schematic Plan 1, Exploring Layout , (Author 2020).*

Schematic Plan Diagram 2.

The corner is defined by a an acute rectangular form which allows visual access into the internal space. This visual porosity allows for communal surveillance as well as acts as an incentive to explore the inside of the space.



The pedestrian Street along Juta street creates a design opportunity for the facade of the building to be interactive. The diagram explores this facade as a manufacturing workshop. How can a productive space be designed in such a way that it has an interactive edge?

Fig 7.1(v): *Diagram of Schematic Plan 2, Exploring Layout , (Author 2020).*

FORM EXPLORATION (Diagram 1)

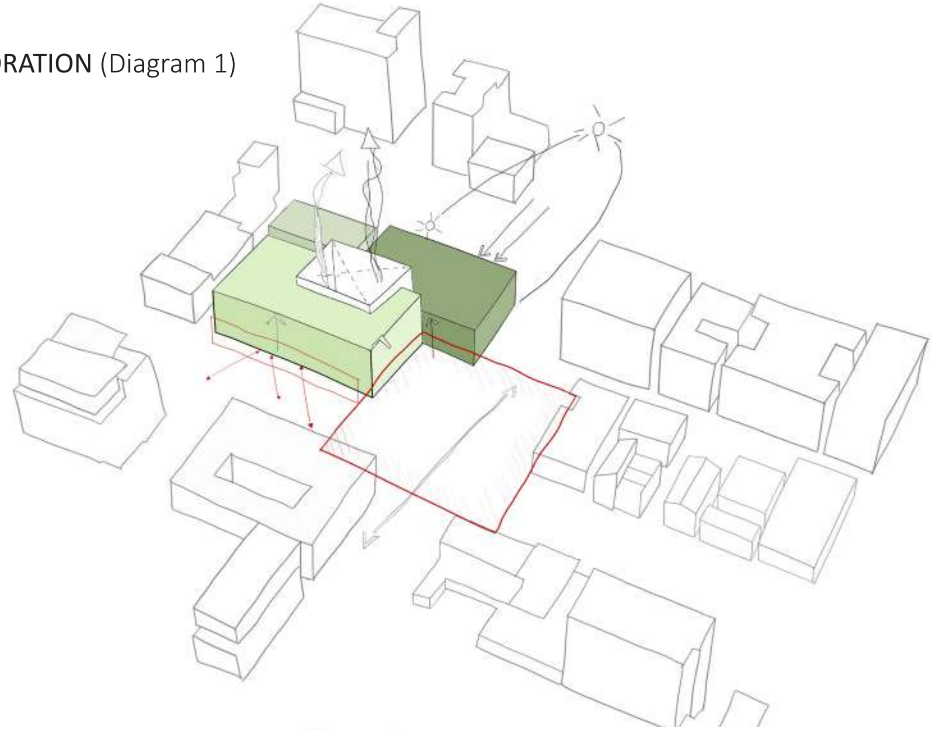


Fig 7.1(vi): *Form Exploration Diagram 1 , (Author 2020).*

FORM EXPLORATION (Diagram 1)

Fig 7.1(vi). Shows the first stage of form generation through context responsive exploration. The diagram illustrates the massing of solid forms driven mostly by program. These define the volume of the spaces and clearly distinguish the various uses. The solid massing is cut into and a central void created to allow natural light into the deep spaces created. The void also induces air circulation and ventilation through the stack effect. On ground-floor the massing steps back to enable the creation of a public square which softens the hard edge of the form.

FORM EXPLORATION (Diagram 2)

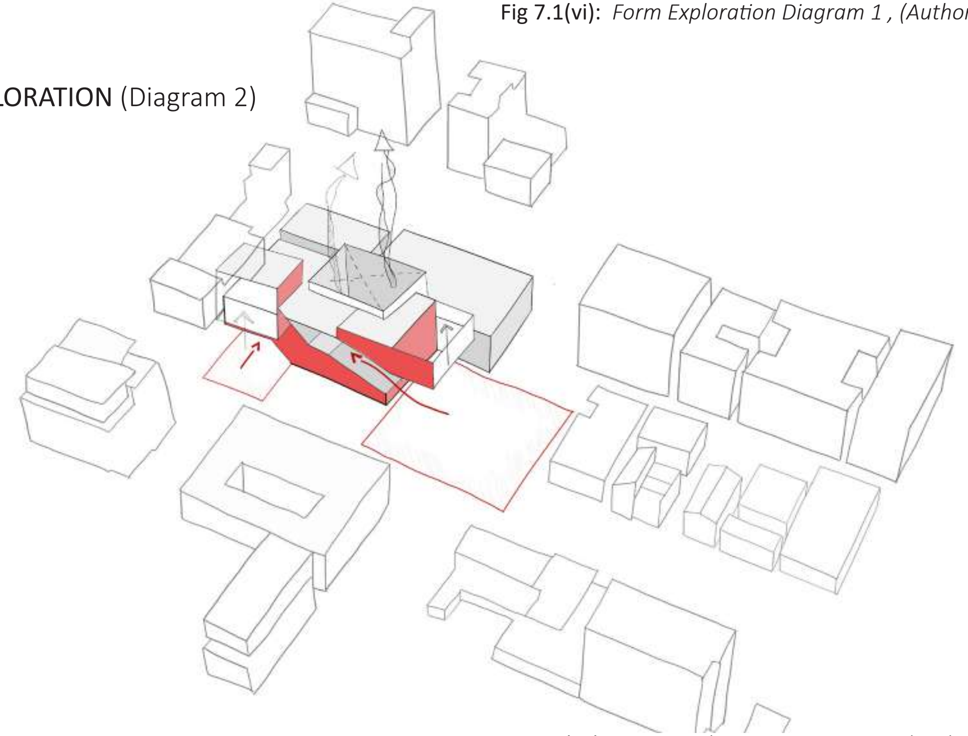


Fig 7.1(vii): *Form Exploration Diagram 2 , (Author 2020).*

FORM EXPLORATION (Diagram 2)

Fig 7.1(vii). Shows the sequential development of the form by layering of complexities. Here the solid bulky massing is broken down into smaller components in order to make the building more permeable and approachable from a pedestrian point of view. The massing becomes more dynamic as the cutaways creat e a feeling of lightness that could tectonically be translated into built form. The roof element of the massing is seen as a dynamic and playful platform that can be as an extension of the ground-floor landscape.

Sketch Ground-Floor Plan.

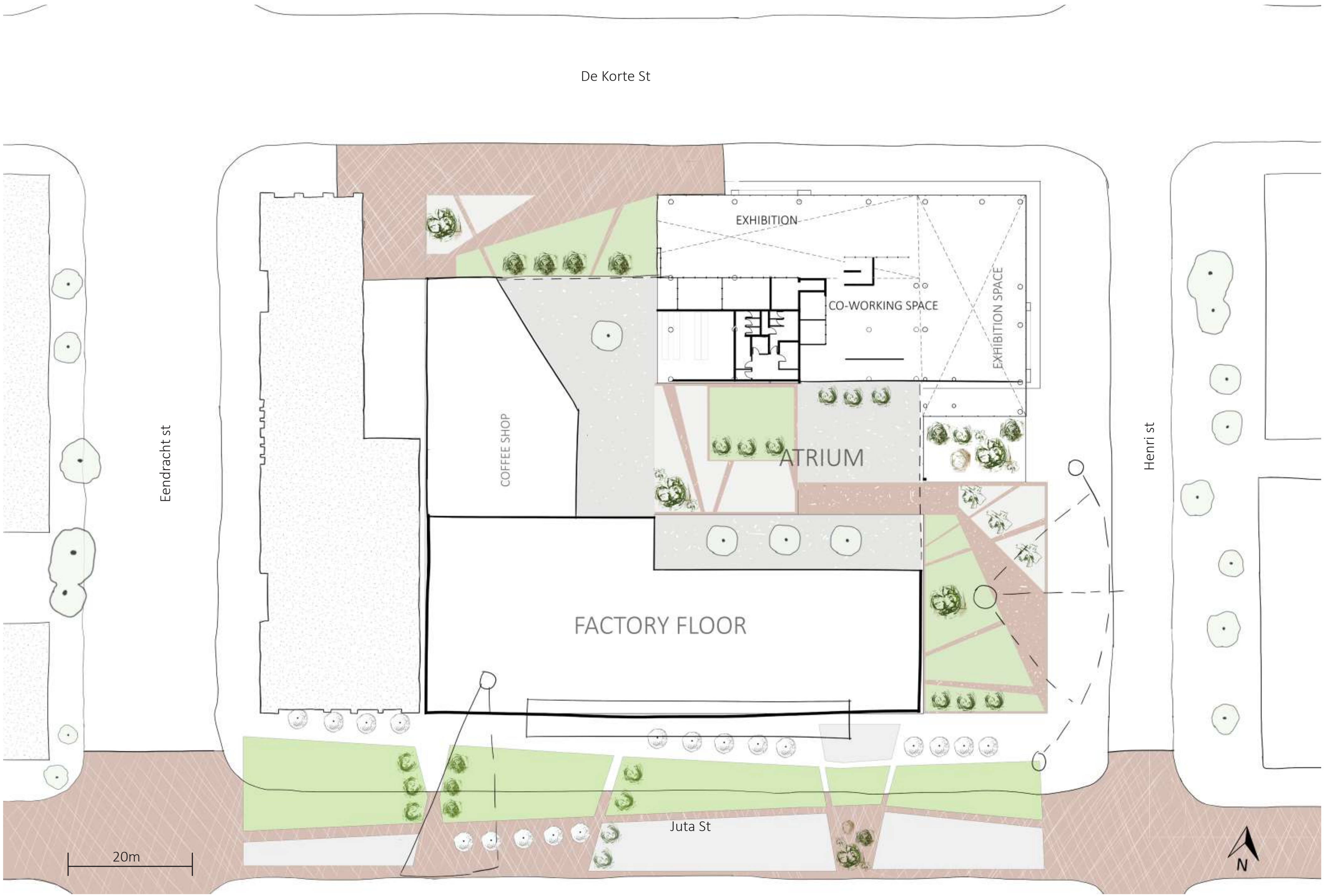


Fig 7.1(viii): *Schematic Sketch Ground Floor , (Author 2020).*

Sketch Cross Section.

Fig 7.1(xi). Explores the idea of a prominent central Atrium space. It shows how a central void could be useful in passive climate control by creating a space that will induce air flow and naturally cool the space. At the same time by creating a central open space with loosely defined space it allows for the user to have visual access to the sky and give the building an airy feeling of lightness.

The diagram highlights the significance of the edges where the street meet the building. In this case by lifting up the building on both edges , a generous accessible space is opened up where pedestrians can theoretically walk across the building from one end to another. Resultantly making the building feel like its part of the urban public infrastructure.

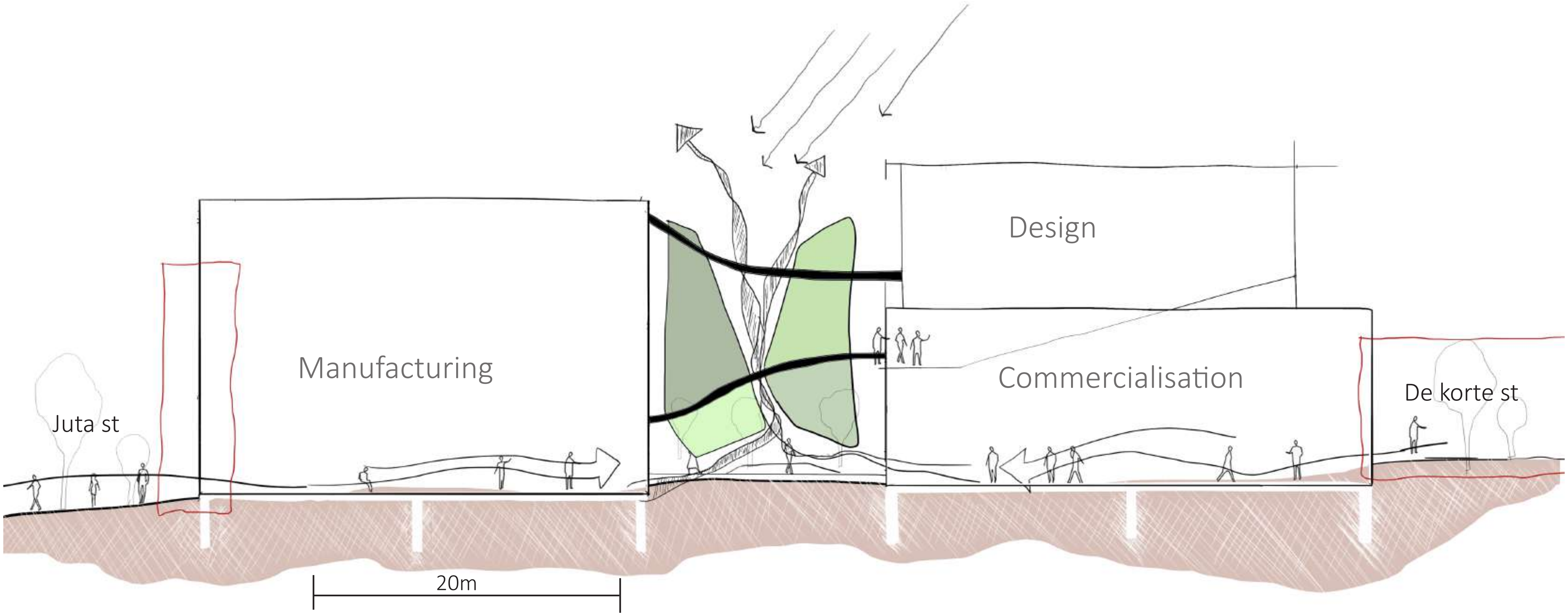


Fig 7.1(ix): *Schematic Sketch Cross Section, (Author 2020).*

Artist Impression "Entrance into Atrium".

Fig 7.1(x): *Collage Capturing Feeling of Space "Entrance to Atrium", (Author 2020).*

Chapter 8
Technical Systems.

SYNOPSIS

The chapter discusses ecological design practices and proposes a system that can be applied to the design proposal. In addition, It also explores the conceptual strategy and thinking behind material choice and construction methodology. Overall the chapter is a critique of the tectonic expression chosen by the author giving insight into the rationale behind the very specific choices.

8.1 Ecological Systems

ECOLOGICAL SYSTEMS.
Background

This chapter looks at how sustainable architecture can actively engage environmental issues caused by rapid urbanisation in the City of Johannesburg. The main design tool used is the application of Integrated Sustainable Roof and Landscape Design System. To fully comprehend the environmental issues faced by Johannesburg, it must be understood that the degradation of urban centres' ecologies and ecosystems is a global phenomenon. Cities, as highly dense built up areas are under immense pressure as their infrastructure can hardly keep up with urbanisation, (Effat et al, 2014). This rapid urbanisation results in the destruction of natural ecological systems such as trees, wildlife habitats and open green spaces. It can be argued from the above that there is need for the built environment to start remedial and responsible design to curtail the catastrophic effects of current urbanisation trends.

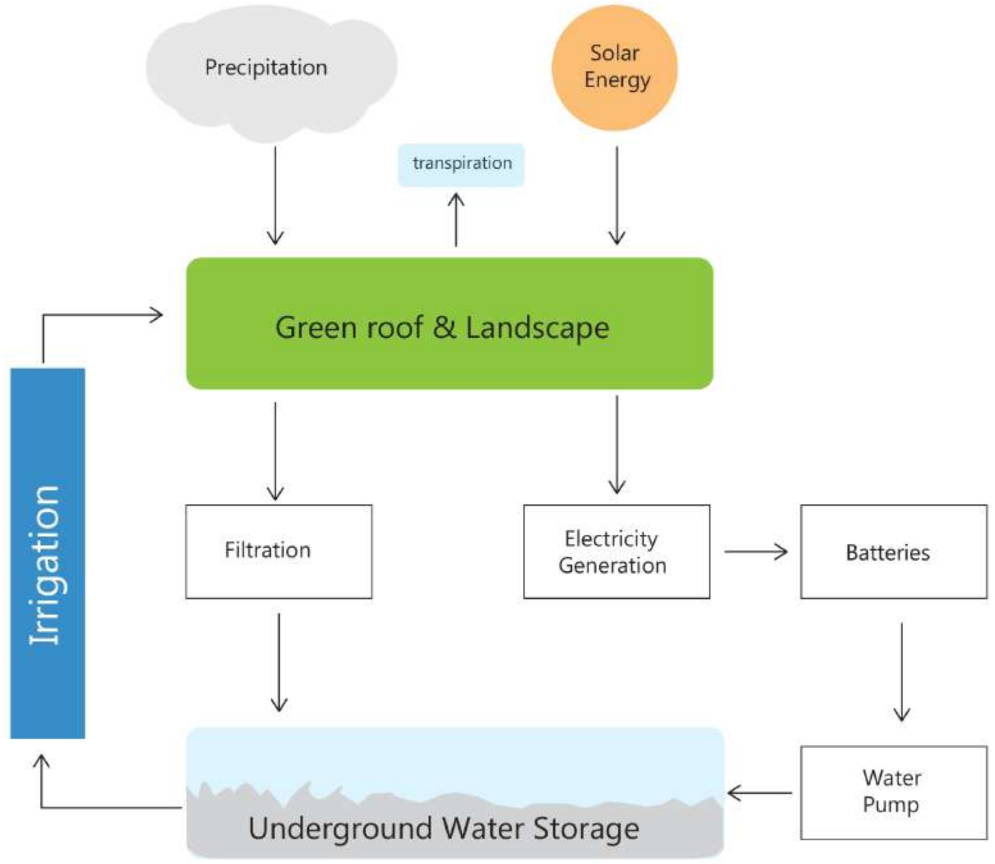


Fig 8.1(i): *Diagram of Integrated Roof and Landscape System Design , (Author 2020).*

INTEGRATED ROOF AND LANDSCAPE DESIGN.

Integrated roof and landscape design is a practice that merges climate, ecology, and technology to come up with environment sensitive and responsive design in an approach known as "ecology architecture". It is comprised of systems that maximise efficiency and comfort as well as promote the health and well-being of users by creating spaces and scenery that are comfortable and aesthetically appealing (Emerson, 2012). The fundamental principle of creating ecological systems that are interdependent will form the basis of the design strategy. This will manifest in the proposed roof and landscape elements.

Fig 8.1(i) illustrates how the roof and landscape of the design proposal will work in a system that will capture rainwater and solar energy, (main inputs), and store them for future use. The process will involve the natural filtration of rain water through specific roof and landscape design and the storage of the water in an underground storage for future use. The solar energy harvested can be used to power the pump that will recycle the stored water for irrigation and other uses. In this way the system is complete and self sufficient. This reduces the design proposal' s carbon footprint, energy requirements and municipal water consumption.

ECOLOGICAL SYSTEMS.
Green Roof Design

Biomimicry is one the key concepts considered in the design of the green roof element of the "Digital Manufacturing Factory". To elaborate further, green roofs allow for natural ecosystems that are diverse to exist and thrive on the roof in the same way they would have on the ground-level. Extensive green roofs represent the "potential for the establishment of shallow soil habitats and their accompanying biodiversity", (Larson et al. 2000). The creation and sustenance of life and natural habitats has an overall positive impact on the larger urban environment ecosystem. Dunnet and Kingsbury (2004), proffer that the "addition of vegetation and soil to roof surfaces can reduce buildings' energy consumption, increase sound insulation, fire resistance, and the longevity of the roof membrane". As an active control mechanism, the green roof can slow down rapid runoff from roofs and other impervious surfaces. Storm-water runoff can be problematic if not managed well because it increases the risk of flooding, erosion, and may result in stress on the sewer system. The green roof is imagined as an opportunity to create usable space and expand the public interface to mitigate the effects of rapid urbanisation such as stormwater runoff and the urban heat island effect.

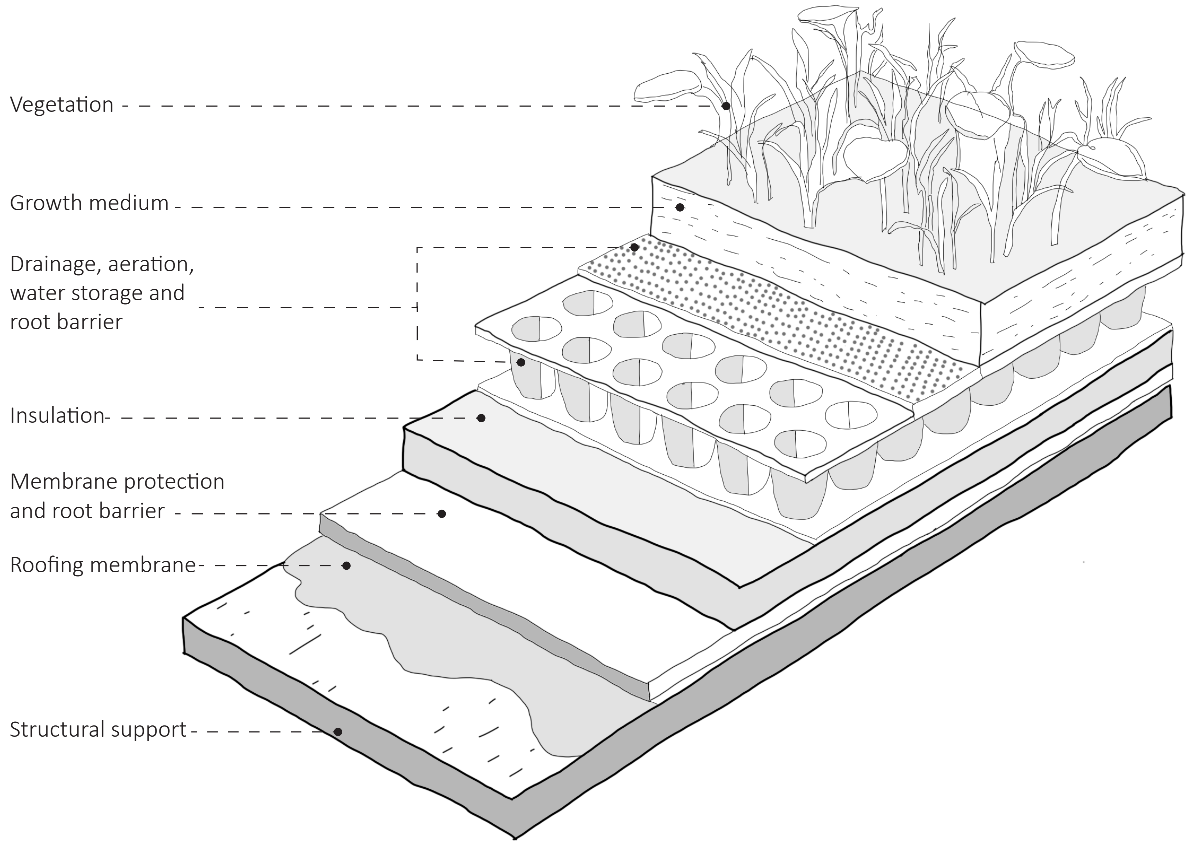


Fig 8.1(ii): *Diagram of an Extensive Green Roof System, Image redrawn by author, (Author 2020).*

An extensive green roof system is going to be applied to the roof of the "Digital Manufacturing Factory". The vegetation planted on extensive green roofs is particularly adapted to harsh environments and is naturally low growing. Consequently, it should be extremely "tolerant of high heat, drought, wind, and frost and must also be self-regenerative in nature as well as have low maintenance requirements overall", (Velazquez, 2005). The author will select plants and vegetation that meet the above criteria and can accordingly be used as green coverage of the roof.

The green roof will collect storm runoff (water harvesting process). The rainwater collected and filtered on the roof is then systematically collected via gutters and taken to underground storage tanks where it is stored. Fig 8.1(ii) shows the layers and components that are required in the construction of the extensive green roof. The vegetation and growth medium (soil and stone aggregates) will act as natural filters capturing particles and toxins before the water is channeled to gutters on the roof membrane, refer to Fig 8.1(ii).

ECOLOGICAL SYSTEMS.
Landscape Design

Green Landscapes in an Urban context have the potential to alleviate the environmental detriments of the built environment as well as create desirable public spaces. Increasing the proportion of inner-city green space and landscapes confronts the devastation caused by the built environment and creates opportunities for social gathering and recreation. Those landscape parameters include vegetation, hard landscapes (walking paths and plazas) and urban furniture with shading devices. Planting vegetation, trees, lawn and other green landscapes allow cooling by transpiration, this process can counter act the urban heat island effect. In addition, tress can form part of the urban infrastructure by providing shade and disrupting waves of solar radiation bouncing back into the atmosphere (Sun et al 2017), refer to Fig 8.1 (iii) . This design approach to urban spaces not only has ecological benefits but encourages "lingering" and "staying which promote human social interaction. It can therefore be argued that urban comfort can significantly be improved by urban greening. This conceptual design approach will inform the landscaping strategy of the design proposal.

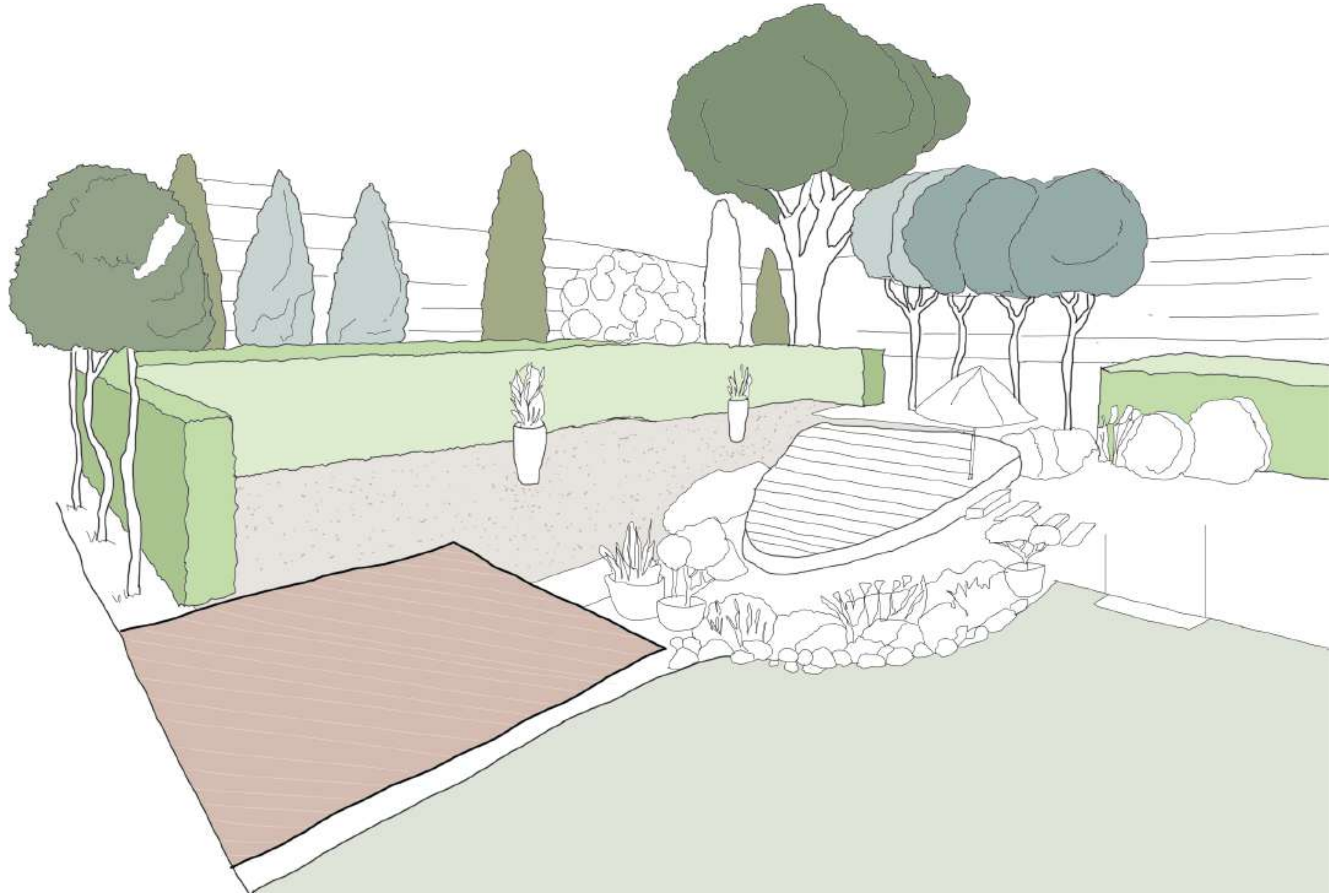


Fig 8.1(iii): *Artist Impression of " Green Landscape Design" envisioned for Digital Manufacturing Factory , (Author 2020).*

From a technical design point of view, the landscape will be constructed from recycled plastic timber (urban furniture and decking), interlocking paving clay bricks (hard landscaping) and lawn as well as local flora (soft landscaping). The choice of material will be based on recycled elements that have a low carbon footprint and embodied energy such as plastic timber and clay bricks made from local raw material. At the same time, the plants and vegetation selection will also be derived from local, drought resistant, low maintenance flora. Fig 8.1 (iii) is a collage which creates a visual impression of some of the afore mentioned ideas.

The landscape will function in conjunction with the green roof by offering increased green surface area that is responsible for the collection and filtering of storm-water runoff. The hard landscaping will act as flood protection and offer a contrast in materiality and durability in parts of the landscape that are heavily used. The landscape will also play the dual role of offering cover and protection for the underground water storage tank.

8.2 Materiality & Construction

The drawing is the first design iteration exploring the possibilities of framed timber and steel construction. It explores the notion of light weight prefabricated construction overlayed with the ecological systems discussed in the previous chapter. Framed construction enables large spans ideal for the traditional factory typology. Triangulation is also introduced to provide structural rigidity.

TECTONIC EXPRESSION.
Design Concept 1

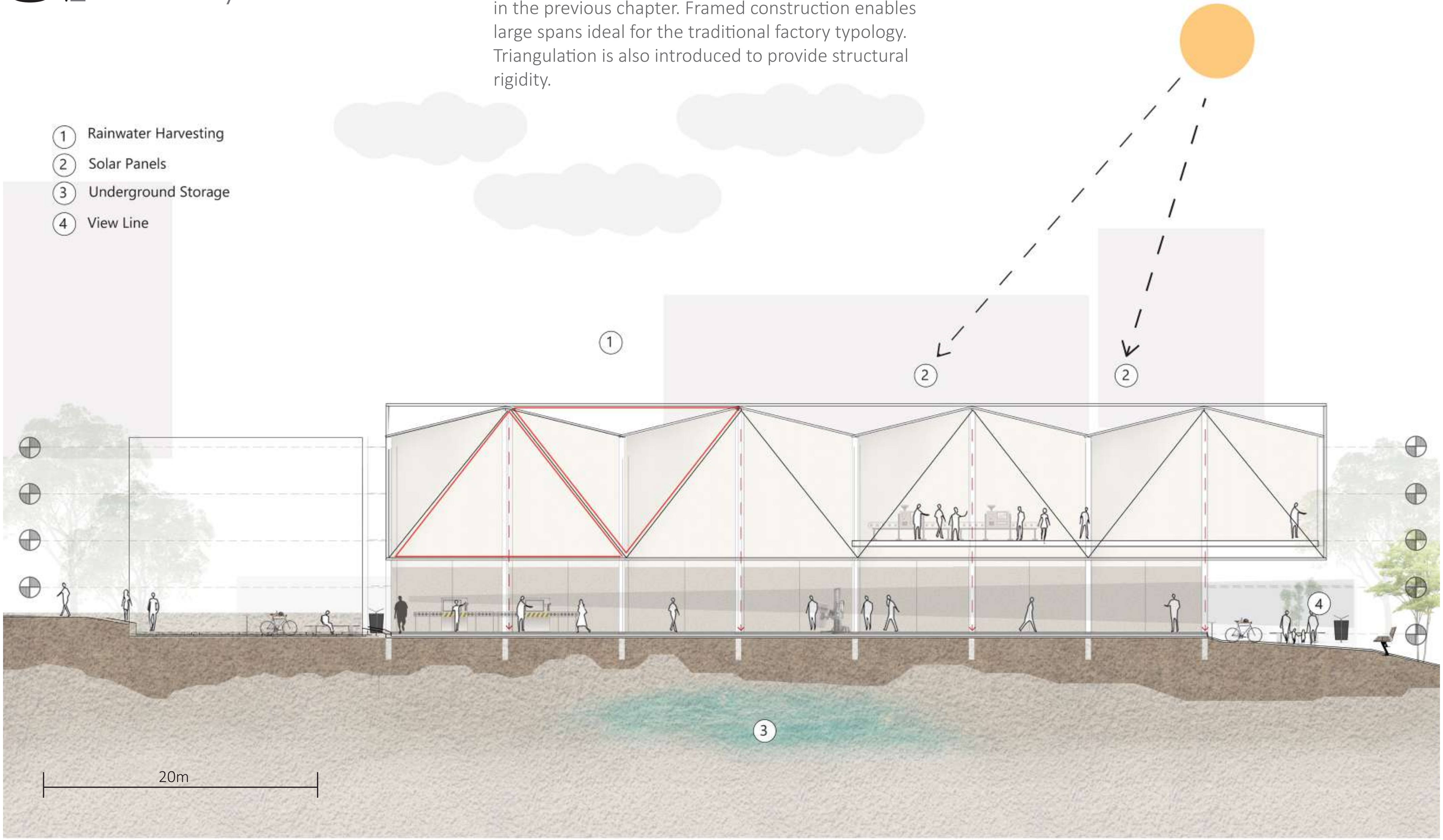
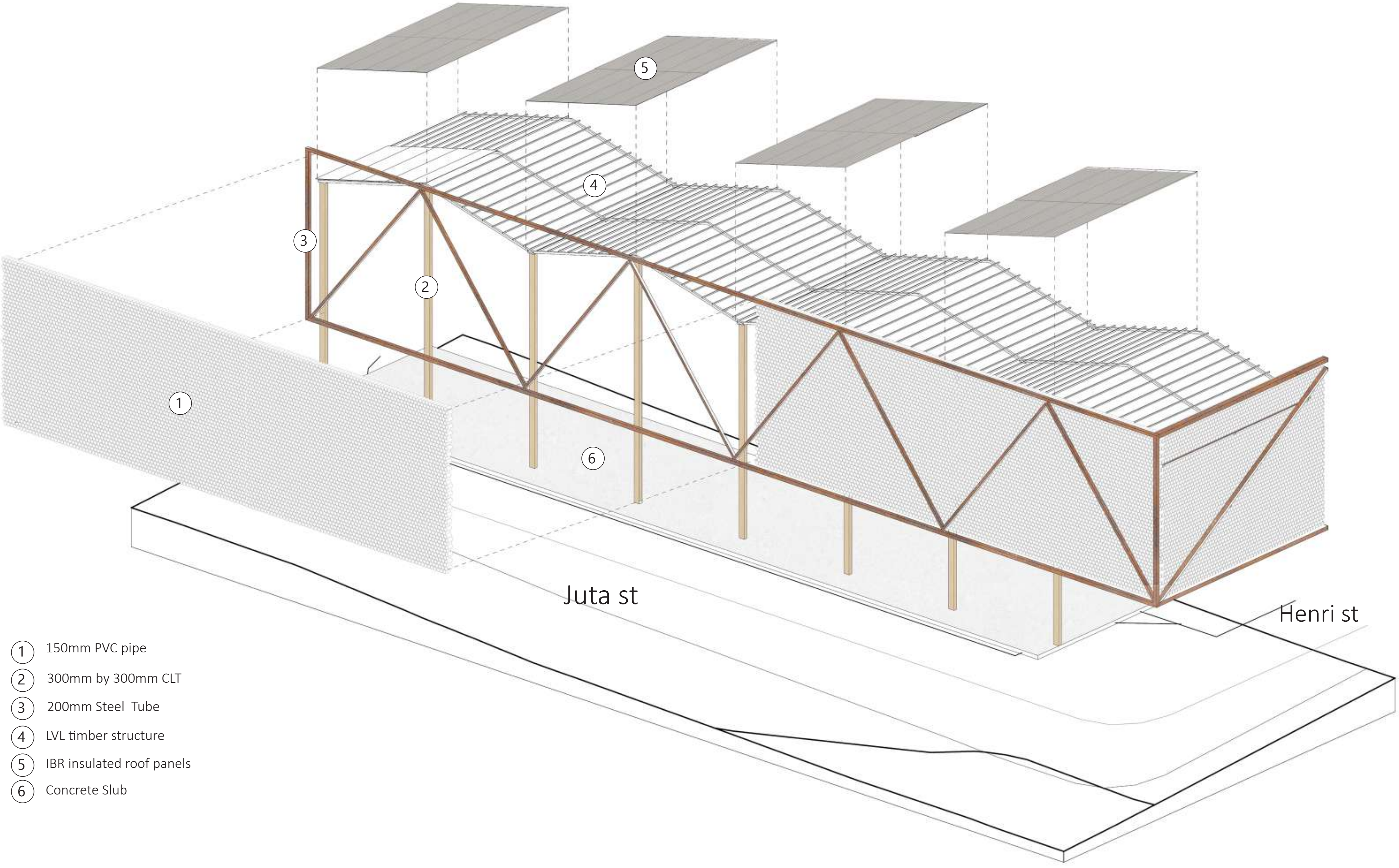


Fig 8.2(i): *Sectional Rendering Exploring Tectonics and Materiality of Design Proposal, (Author 2020).*

TECTONIC EXPRESSION.
Design Concept 1



1. 150mm PVC pipe
2. 300mm by 300mm CLT
3. 200mm Steel Tube
4. LVL timber structure
5. IBR insulated roof panels
6. Concrete Slub

Fig 8.2(ii): *Exploded Axonometric Drawing Exploring Tectonics and Materiality of Design Proposal, (Author 2020).*

Axonometric Rendering of Juta St .

The axonometric rendering captures the feeling of the space created along the Juta st threshold. It is the culmination of the tectonic expression driven by lightness and precision combined with the green landscaping design strategy discussed earlier in this chapter.

The result is a porous and interactive edge that conceptually denotes the extension of the public realm into the building. However, the strong linear minimalist architecture resulting from the exploration fails to capture the energy, vigor and ambition of earlier concepts.

TECTONIC EXPRESSION.
Design Concept 1

Fig 8.2(iii): *Exploded Axonometric Drawing Exploring Tectonics and Materiality of Design Proposal, (Author 2020).*

As has been argued in the theoretical underpinnings of this discourse, disruption and innovation is a phenomenon to be embraced. What is disruption in the architectural realm? How does a building designed to foster disruption embody the same concept?

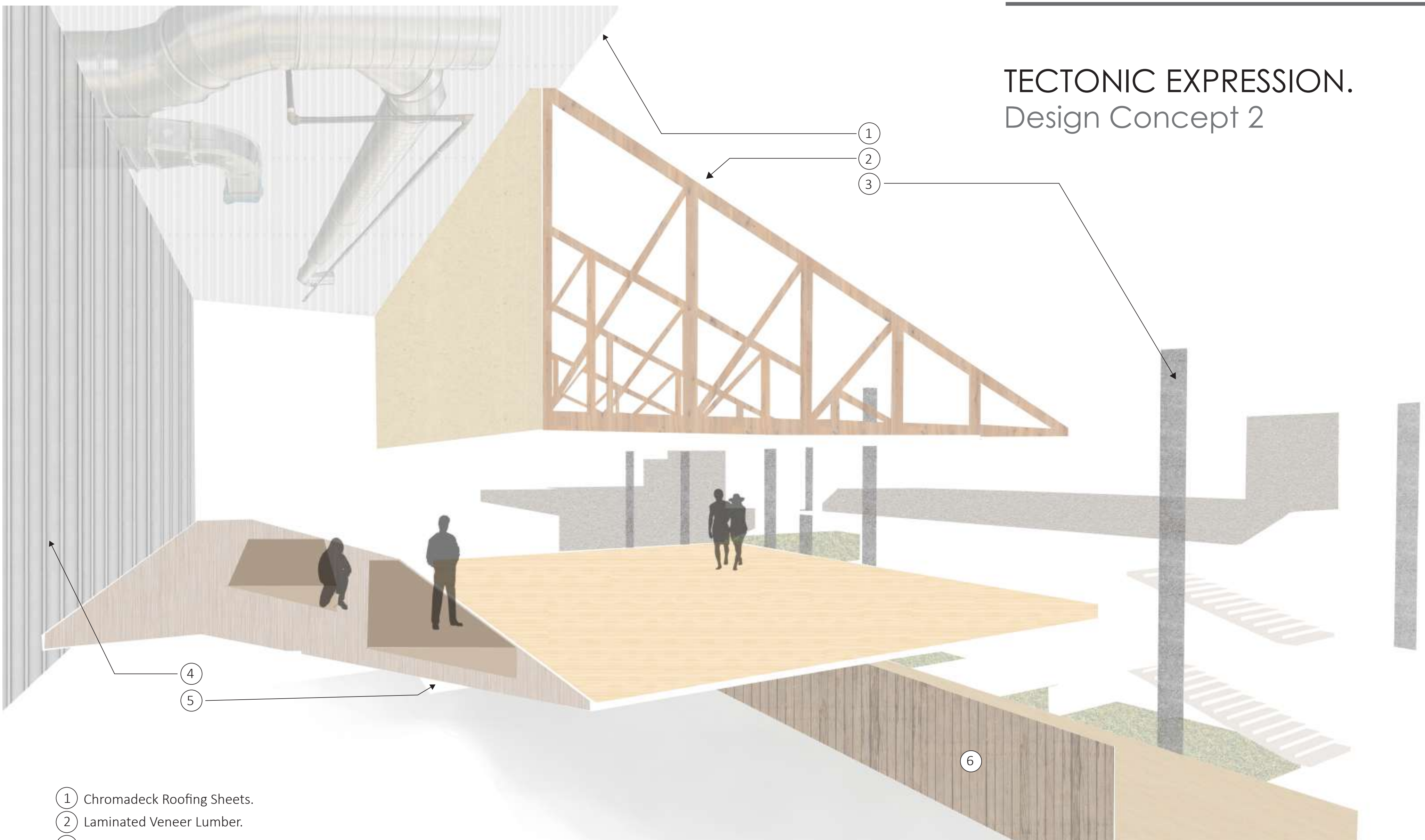
The author propounds that the design proposal should be a radical rebuff of convention. The proposed building should break away from the control and restrictions of grids, symmetry and harmony. It should be a manifestation of the complexity and simplicity of the creative ideas it seeks to develop, refer to Fig 8.2(iv).

TECTONIC EXPRESSION.
Design Concept 2

Fig 8.2(iv): *Perspective Drawing Exploring Deconstructivism Tectonics, "View from Juta st" (Author 2020).*

TECTONIC EXPRESSION.

Design Concept 2



1. Chromadeck Roofing Sheets.
2. Laminated Veneer Lumber.
3. Concrete Column.
4. Synthetic Glass Polycarbonate Sheets.
5. Cross Laminated Structural Slab.
6. Cross Laminated Structural Wall.

The diagram attempts to rationalise the fragmented nature of deconstructivism experimentation. Fig 8.2(v) captures the sculptural freedom enabled by a departure from convention. A clear understating of materiality is also shown in the diagram, perhaps making the concept feasible? It is however clear that there is room for more exploration and discipline in the next iteration.

Fig 8.2(iv): *Sectional Perspective Drawing Exploring Deconstructivism Materiality, "View from Juta st" (Author 2020).*

Chapter 9
Design Development.

SYNOPSIS

This chapter is comprised of the final design development process that informs the resulting final design proposal. It is an account of the prominent and resilient concepts that would have shaped the final building program, form and tectonics. In this particular chapter a series of diagrams and tectonic graphics are shown to show the final ideas that would be translated into architecture.

9.1 Final Design Development

Fig 9.1(i) Illustrates the final design development through massing exploration. The diagram captures the final form exploration as a result of extentensive design experimentation and form finding process highlighted in previous chapters of this research. To be specific, the final form shown in Fig 9.1(i) highlights a few key design ideas that have proved vital throughout this book's investigation and exploration.

Firstly, the main concept of a central atrium with dual function has been retained and forms the core of the design development massing illustrated in Fig 9.1(i). The central incision creates a void of space that can be occupied as public space as well as play a key central role in the passive cooling system of the building. This central feature of the form and massing is complemented by a cut back of the building along De korte to create a moment of pause and along Henri street to form a public square. The public square is framed by adjacent buildings whose thresholds act as a backdrop to a square which is open and porous allowing access for everyone. The three cut away spaces on the centre and edges of the building form the larger urban response , with various opportunities provided for spontaneous and informal exchange.

Secondly, clear articulation of the edge along pedestrianised Juta street, together with creation of a roof top garden are some of the resilient concepts that are shown on Fig 9.1(i). The street edge along Juta street offers a clear opportunity to engage the public both visually through the design of a facade and physically by the clear demarcation of boundaries that can offer seating and moments of pause. At the same time the roof top garden plays a vital ecological role as it helps filter and store water. This ecological function is layered by the recreational facilities offered at the roof top garden. Resultantly the building is enveloped by the public interface.

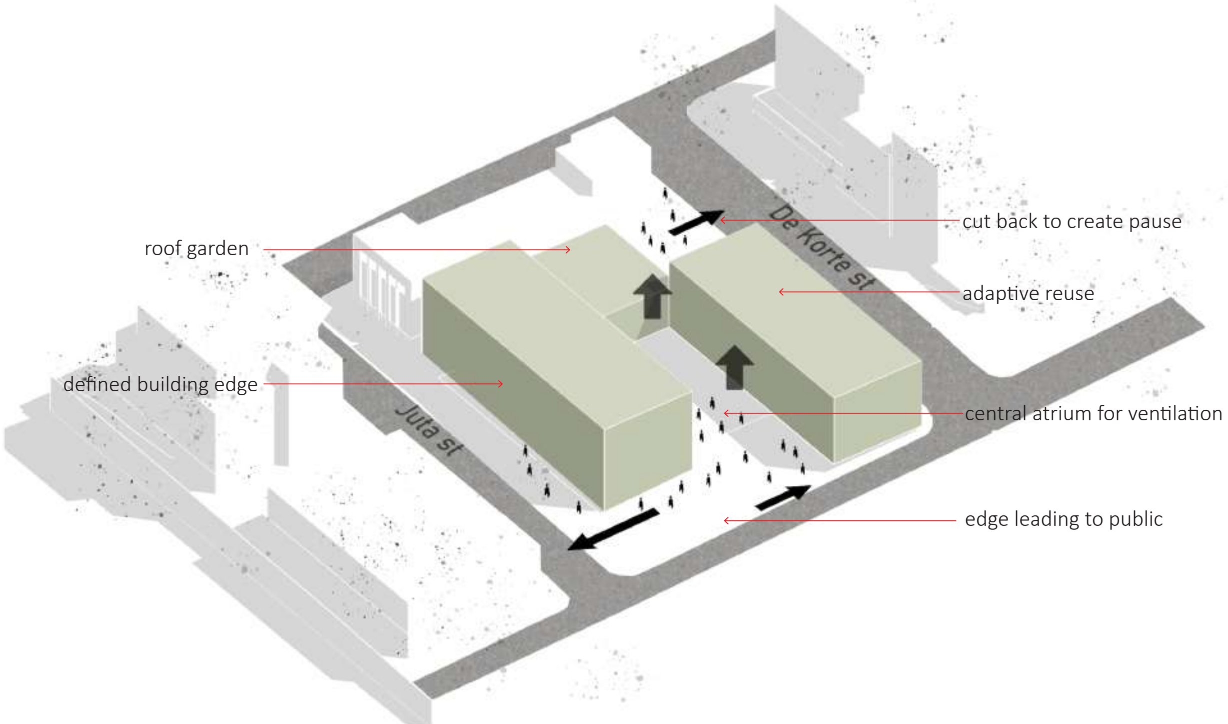


Fig 9.1(i): *3D Axonometric Diagram illustrating Final Design Development (Author 2020).*

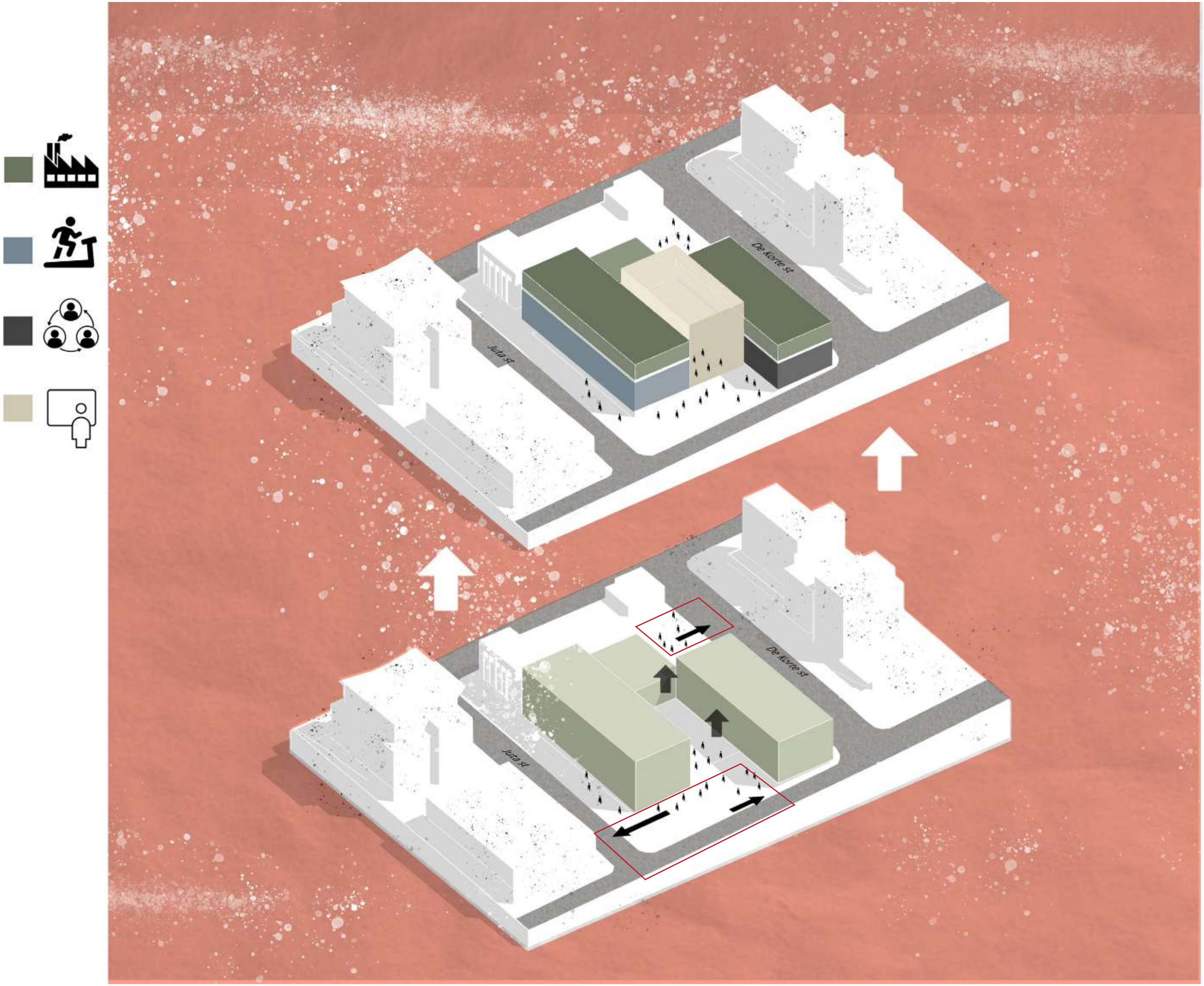


Fig 9.1(ii): *Series of 3D Axonometric Diagram illustrating Final Design Development (Author 2020).*

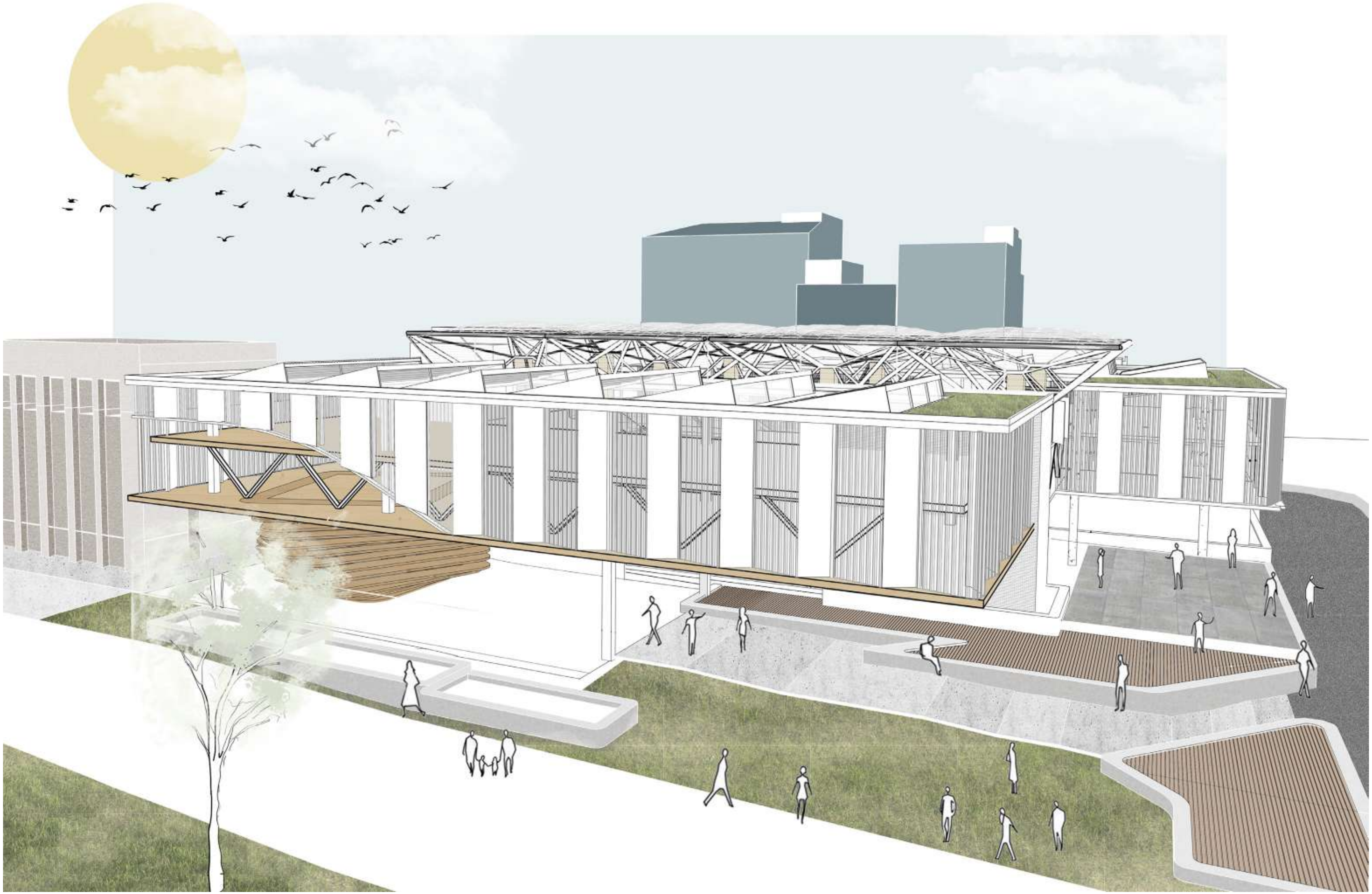


Fig 9.1(iii): *3D Tectonic Exploration along Juta st Final Design Development (Author 2020).*

Fig 9.1(iv): *3D Tectonic Exploration Corner Juta and Henri st, Final Design Development (Author 2020).*

Chapter 10
Final Drawings.

SYNOPSIS
The final technical drawings, details and presentation graphics are shown in this chapter. These drawings form the core of the architectural intervention. They highlight the final product of the extensive research and exploration carried out in the rest of this book. The conclusion to the research is also included in this chapter.

Fig 10.1(i): *3D Perspective, Visualisation of Final Design Proposal, Corner Juta & Henri st. (Author 2020).*

Fig 10.1(ii): *Ground-floor Plan of Final Design Proposal. (Author 2020).*

Fig 10.1(iii): *3D Visualisation of Central Atrium, Final Design. (Author 2020).*

Karabo

Melusi

Chris

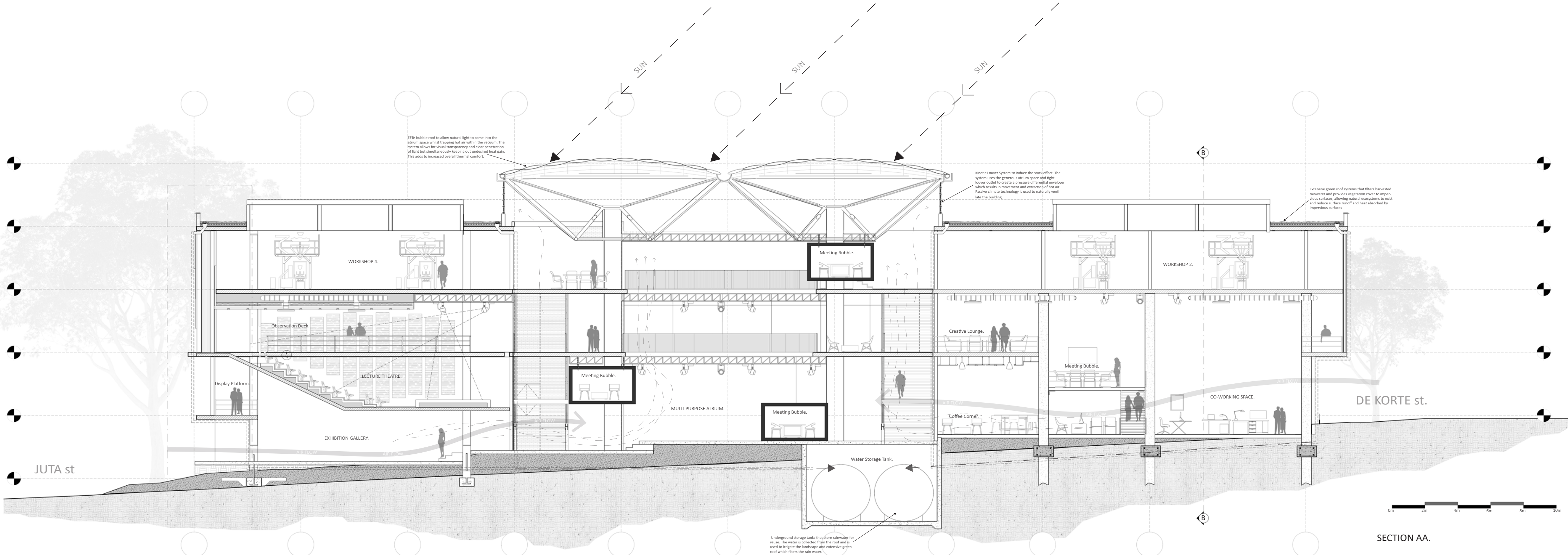


Fig 10.1(iv): *Cross Section of Final Design Proposal. (Author 2020).*

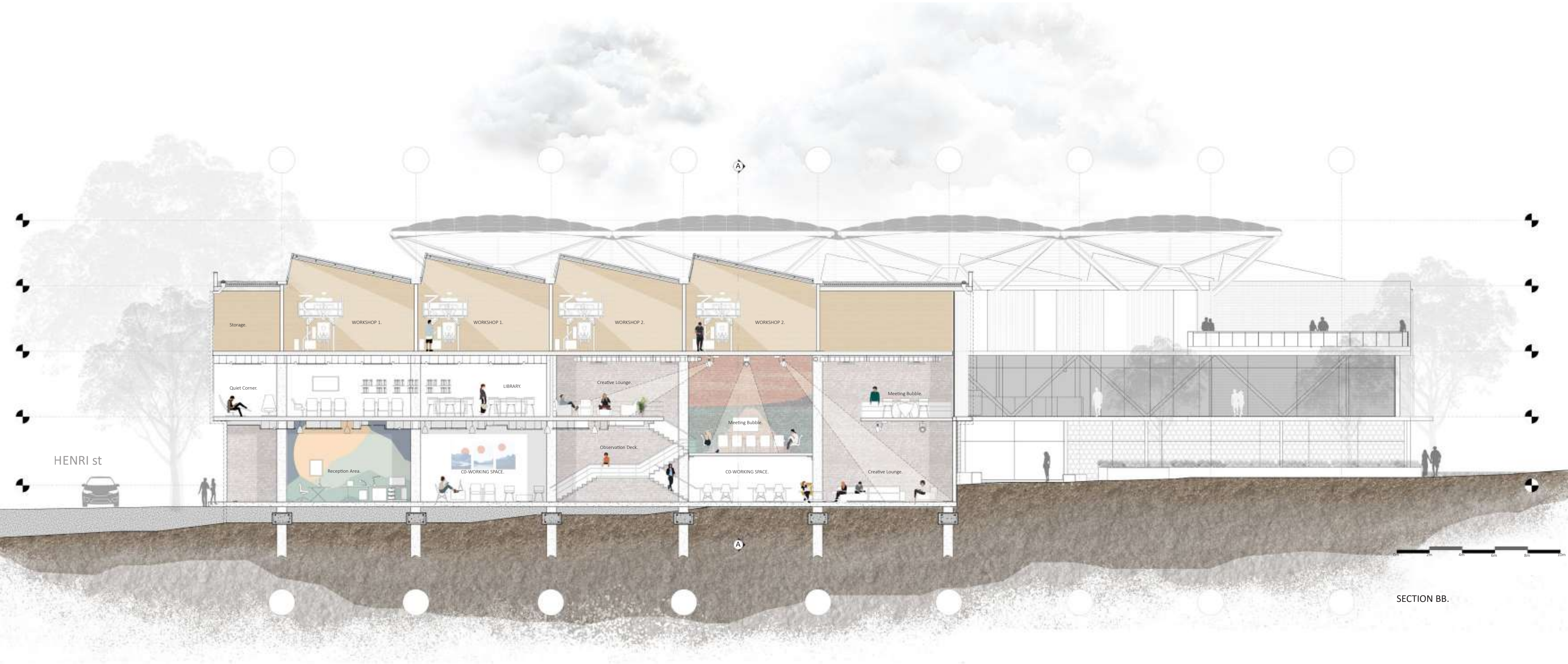


Fig 10.1(v): *Longitudinal Section of Final Design Proposal. (Author 2020).*

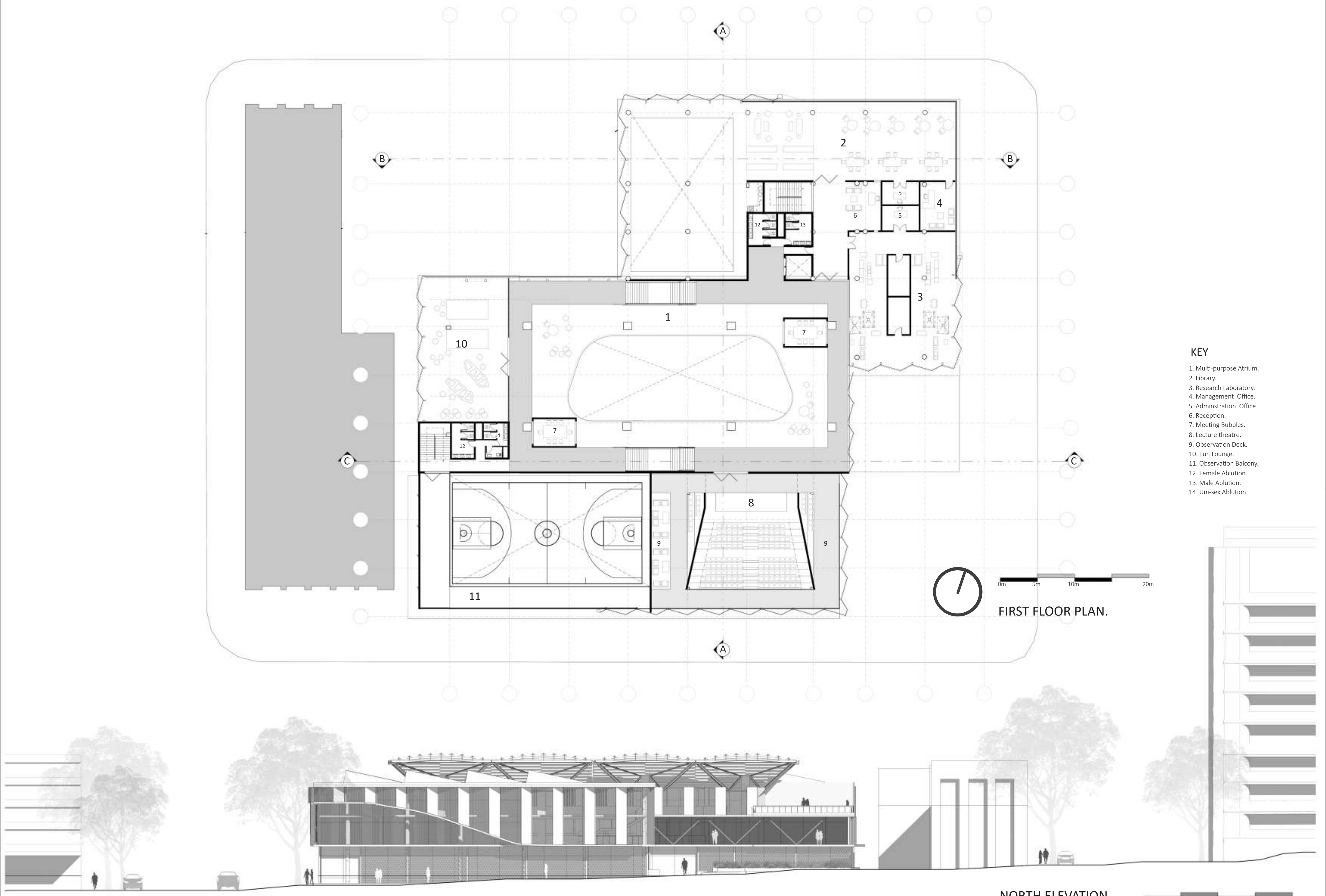
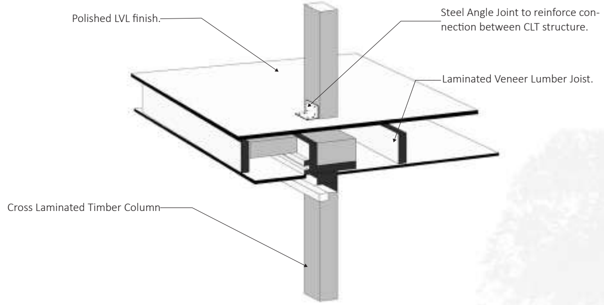
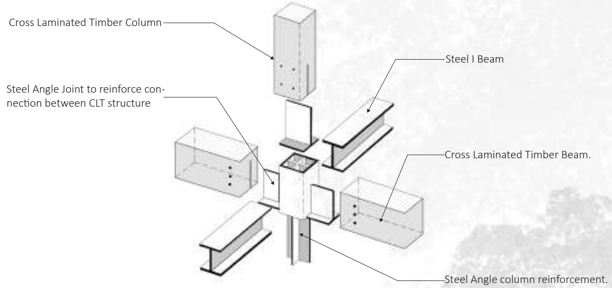


Fig 10.1(v): *First-floor and North Elevation of Final Design Proposal. (Author 2020).*



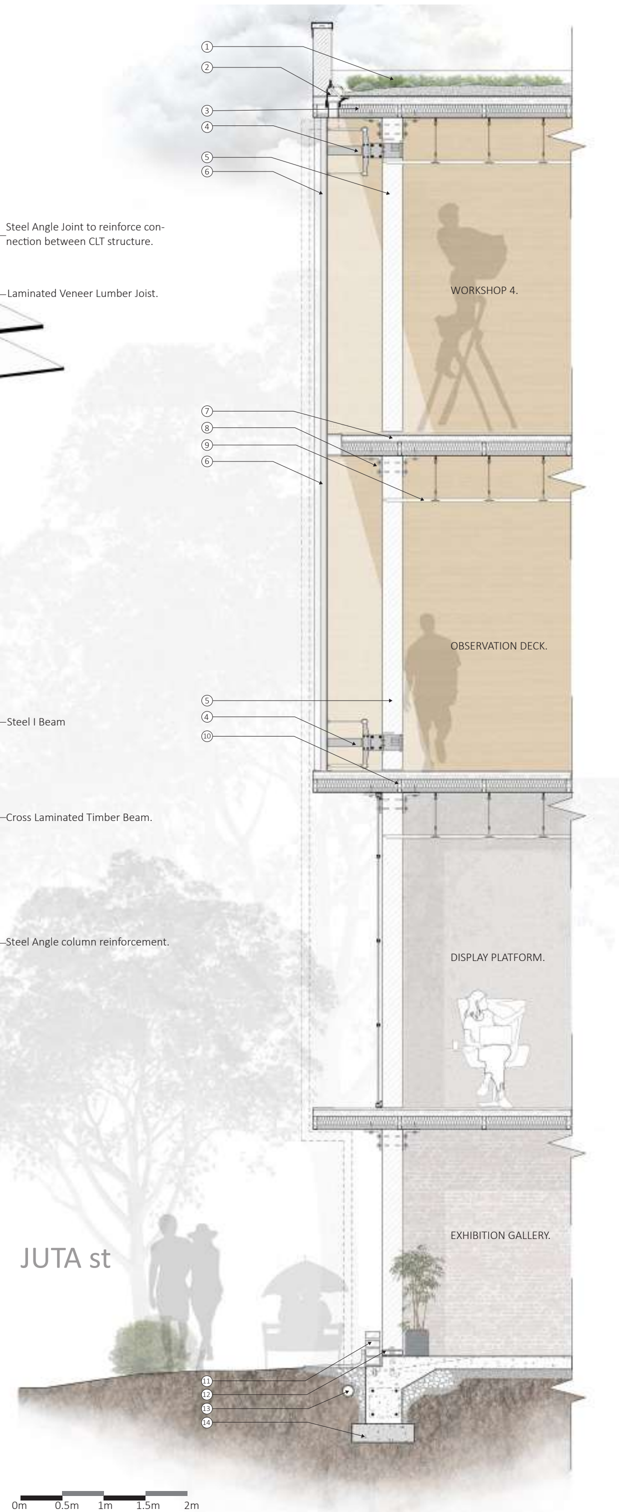
FRAMED CONSTRUCTION (3D Detail: Wood Column to Wood Floor)



FRAMED CONSTRUCTION (3D Detail: Wood to Steel Structure)

KEY

1. Extensive green roof plants and vegetation.
2. Full bore outlet, collects rainwater.
3. Insulation layer under structural beam.
4. Pivoting steel anchor, (building envelope support.)
5. Cross Laminated Timber Column.
6. Synthetic Glass Polycarbonate Sheets.
7. Cross Laminated Structural Slab.
8. Steel Angle Structural Support.
9. Suspended Ceiling.
10. Laminated Veneer Lumber Joist.
11. Single Brick Course.
12. Anchor Bolt.
13. Drain Tile in Gravel Bed.
14. Strip foundation footing.



SECTION AA CALL OUT.

Fig 10.1(vi): *3D Tectonics and Detailing of Final Design Proposal. (Author 2020).*

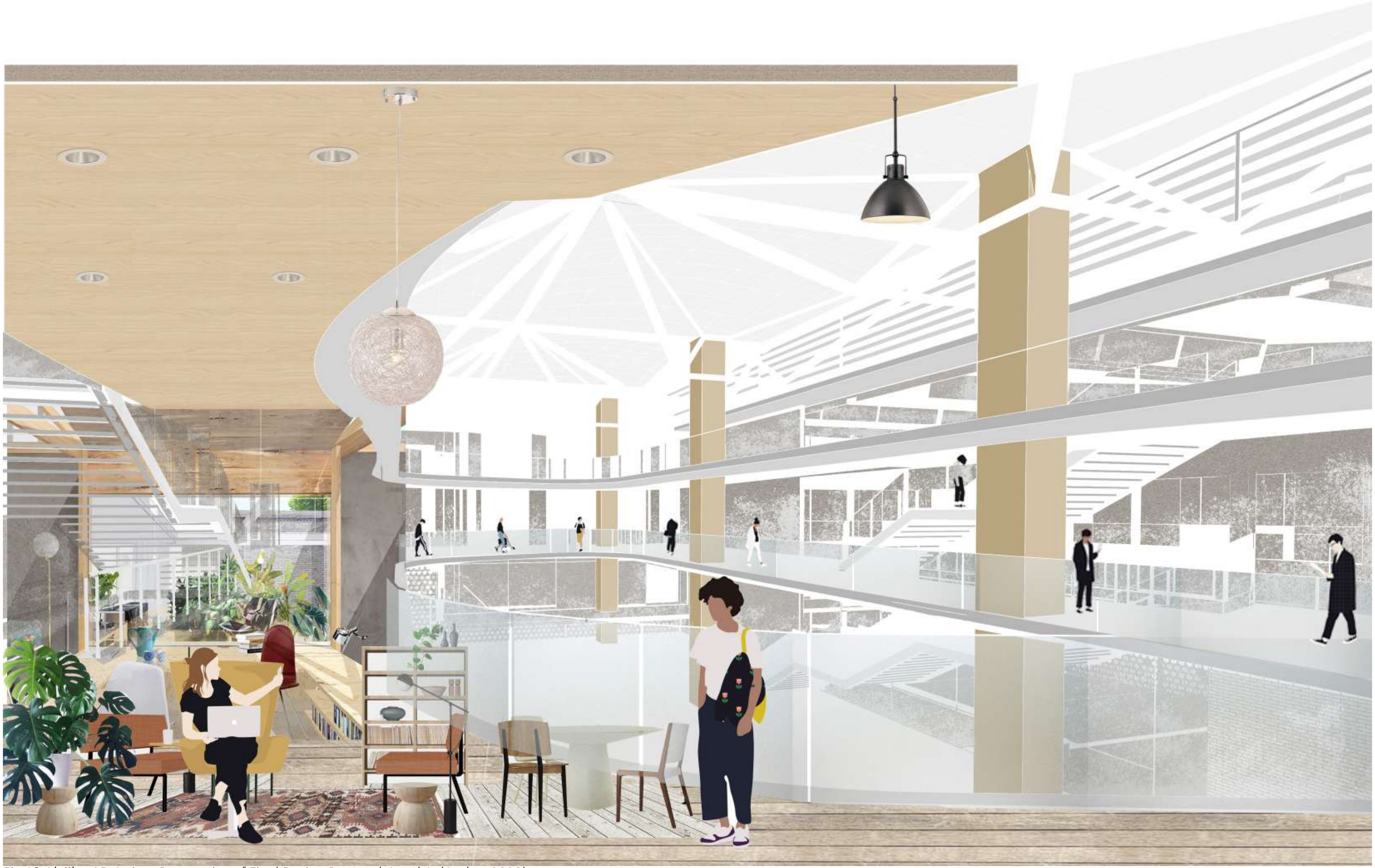


Fig 10.1(vii): *3D Atrium Perspective of Final Design Proposal, Level 1. (Author 2020).*

Fig 10.1(viii): *3D Atrium Perspective of Final Design Proposal, Level 2. (Author 2020).*

10.2 Conclusion & Reflection

This research sort out to harness the power of technology and innovation as a means of developing local manufacturing and manpower. Digital manufacturing is still in its relative infancy in the South African context and as such local precedents and skill is still limited. Such a deficiency in the knowledge and skill base further reinforces the need for more investments in the field of digital manufacturing. I as an individual, through this architectural discourse have become more knowledgeable and informed about the potential of this field. Although my research with regards to the above was not exhaustive, it pointed out to there is a need for architecture as a built form to engage with contemporary issues and offer relevant responses.

The Braamfontein context proved to be a rich resource for information and guidance throughout this project. Dense, Urban areas as I was to discover, offer a plethora of design opportunities that can have a big impact on the lives of a multitudes of people. What I found to be particularly interesting was the linkages between research (Wits University), a young skilled demographic and unemployment as an ideal set of conditions for the development of Factory.

Overall the design proposal was the culmination of the revolutionary ideas on technology as well as local contextual adaptation of concepts driven from adaptive reuse, sustainability and others. The resultant architecture attained a level of functionality and pragmatism which justify the preceding research inputs adequately. The form and facades of the building could have immensely benefitted from a more rigorous exploration process, the outcome however, is sufficient and satisfactory. In summation, this project is the product of resilience and passion under extremely difficult conditions. The Covid 19 pandemic meant that the research had to be conducted using relatively new methodologies. I am however grateful for the support structures and inputs that have resulted in the culmination of this book.

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List of Sources.

Andres Dueng: The Traditional Neighbourhood and Urban Sprawl. *New Urbanism and Beyond*. Designing Future Cities, 2008.

Andrew King (2015): How Useful Is the Theory of Disruptive Innovation? MITS loan Management Review.

Bremner, L. 2000. "Reinventing the Johannesburg Inner City." Cities 7 (13): 185–93.
Conejos, Sheila (2013): Doctoral Thesis. "Designing for Future Building Adaptive Re-use" Bond University.

Douglas Kelbaugh: Three Urbanisms. New Urbanism and Beyond. Designing Future Cities, 2008.

David B. Audretsch and Maryann P. Feldman: R&D Spillovers and the Geography of Innovation and Production. The American Economic Review, Vol. 86, No. 3 (June, 1996)

P. Thomond & F Lettice (2002): "Disruptive Innovation Explored", Concurrent Engineering Conference Proceedings July 2002.

Enrica Papa & Dirk Lauwers (2015): "Smart Mobility, Opportunity or Threat to Innovate in City" Department of Civil Engineering Center for Mobility and Spatial Planning Ghent University.

Gerben van der Panne (2004): Agglomeration externalities: Marshall versus Jacobs, Department of Economics, Delft University of Technology.

Glenn Lyons (2016): Getting smart about urban mobility – Aligning the paradigms of smart and sustainable. Centre for Transport & Society, Faculty of Environment and Technology, University of the West of England, Frenchay Campus, Bristol.
Ian Brinkley :Defining the Knowledge Economy. The Work Foundation (2006).

Greenfield, J. (2012, December 6). Danish History: How Copenhagen became bike-friendly again. Retrieved February 12, 2015, fromhttp://gridchicago.com/2012/danish-history-how-copenhagen-became-bike-friendly- again.

Hans Jeekel (2016).Social Sustainability and Smart Mobility: Exploring the relationship. World Conference on Transport Research- WCTR 2016 Shanghai. 10-15 July 2016.

Jay Lee (2015): Smart Factory Systems: Ohio Eminent Scholar and L. W. Scott Alter Chair Professorin Advanced Manufacturing, Univ. of Cincinnati, Cincinnati, USA.

Jon-Arild Johannessen and Bjørn Olsen (2010), The future of value creation and innovations: Aspects of a theory of value creation and innovation in a global knowledge economy.

Kevin Lynch. The Image of The City, MIT Press, 1960, Boston.

Ksenia Shubenkova, Aleksey Boyko, Polina Buyvol (2018):The technique of choosing a safe route as an element of smart mobility. Thirteenth International Conference on Organization and Traffic Safety Management in Large Cities

Mohd Aiman Kamrul Bahrin and others (2016) "A Review on Industrial Automation" Centre for Artificial Intelligence and Robotic, Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia.

Monika Szopinska-Mularz and Steffen Lehmann. (2019): Urban Farming in Inner-city Multi-storey Car-parking Structures- Adaptive Reuse Potential. Future Cities and Environment.

Özen Eyüce and Ahmet Eyüce (2010): "Design Education for Adaptive Re-use." Special Volume: Design Education: Explorations and Prospects for a Better Built Environment Ashraf M. Salama and Michael J. Crosbie (editors).

Peter A. Bullen (2007): Adaptive reuse and sustainability of commercial buildings. Department of Construction Management, Curtin University of Technology, Perth, Australia.

Rob Krier, Urban Space, Rizzoli International Publications, Michigan 1979.

Victor Knee (2013). Emergence of Knowledge Economy : Social Dynamics of Morphogenesis. Cornell University.

Stefano Breschi And Franco Malerba (2014): The Geography of Innovation and Economic Clustering: Some Introductory Notes. Industrial and Corporate Change.

Victor Knee (2013). Emergence of Knowledge Economy : Social Dynamics of Morphogenesis. Cornell University.

Additional Documents.

SCHOOL OF ARCHITECTURE AND PLANNING
HUMAN RESEARCH ETHICS COMMITTEE

CLEARANCE CERTIFICATE
PROTOCOL NUMBER: SOAP021/03/2020

PROJECT TITLE:	Disruptive Innovation: Harnessing Braamfontein's Knowledge Economy to develop a Smart Mobility Factory.
INVESTIGATOR/S:	Ngonidzashe Tavuyanago (Student No: 1171540)
SCHOOL:	Architecture and Planning
DEGREE PROGRAMME:	Master of Architecture Professional (MArch Prof)
DATE CONSIDERED:	09 May 2020
EXPIRY DATE:	09 May 2021
DECISION OF THE COMMITTEE:	Approved

CHAIRPERSON ______________________
(Dr Brian Boshoff)

DATE: (Signed electronically under lockdown: 10.5.20).

cc: Supervisor/s: Ludwig Hansen

DECLARATION OF INVESTIGATORS
I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to endure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee.

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14 September 2020
Person No: 1171540
TAA

Mr N Tavuyanago
16440 T, Kubatana R, West Masvingo Zimbabwe
00263
Zimbabwe

Dear Mr Ngonidzashe Tavuyanago

Master of Architecture (Professional): Change of title of research

I am pleased to inform you that the following change in the title of your Research Report for the degree of **Master of Architecture (Professional)** has been approved:

From:	**DISRUPTIVE INNOVATION; Harnessing Braamfontein¿s Knowledge Economy to develop a Smart Mobility Factory.**
To:	**Disruptive Innovation: Harnessing Braamfontein's knowledge economy to develop a digital manufacturing factory.**

Yours sincerely

Mr Yaseen Stoffberg
Faculty Registrar
Faculty of Engineering and the Built Environment