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# RESEARCH REPORT

# The role of Innovative Building Technologies in self-build architecture to facilitate sustainable human development in the informal housing context of South Africa.

*A study into the current climate of the IBT industry in South Africa, the relevant legislation, the dilemma of public perception and how this relates to a self-build typology.*

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## DECLARATION OF ORIGINALITY

I declare that the mini-dissertation, The role of IBTs in self-build architecture to facilitate sustainable human development in the informal housing context of South Africa, which has been submitted in fulfilment of part of the requirements for the module of DIT 801, at the University of Pretoria, is my own work and has not previously been submitted by me for any degree at the University of Pretoria or any other tertiary institution.

I declare that I obtained the applicable research ethics approval in order to conduct the research that has been described in this dissertation.

I declare that I have observed the ethical standards required in terms of the University of Pretoria's ethic code for researchers and have followed the policy guidelines for responsible research.

Signature:

Date: 24 / 07 /2023

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## Abstract

Within the South African Human Settlement context there is a growing need for socio-economic development and infrastructure improvement. Social capital, community integration, the local economy, and levels of education are key indicators of citizen well-being in the country. Currently citizens are left wanting when it comes to governmental aid programmes dealing with service delivery and provision of basic housing. Both these areas of concern are not seeing consistent and overall promising improvements. The aim of this study is to establish a basic understanding of the potential offered by Innovative Building Technologies as a possible solution to the infrastructural backlog (especially in the provision of housing and places for economic activities). UN-Habitat suggests that *in-situ* upgrades to existing structures are the most effective approach to address the current housing challenges (Chenwi, L., 2012). This study proposes self-build practices as a means of achieving such upgrades, involving owners or residents in the planning, design, and construction processes for the upgrading developments. To this end, an improved sense of ownership and stewardship can be fostered, and the country's development can become a community effort. Within this social climate, the culture and practice of self-build exists in the informal settlements sector with the use of found objects. The proposed relationship between IBTs and self-build architecture is considered to cause a paradigm shift as a new model for South Africans to participate in building their own neighbourhoods in a sustainable manner that is both incremental and uniquely suited to the contextual requirements of each geographical region. The study investigates the regulatory context's role, including the Department of Human Settlements, Agrément South Africa, and the National Home Builders Registration Council, in shaping policies and influencing the adoption of IBTs within the Architecture, Engineering, and Construction industry. Findings highlight the importance of promoting and developing IBTs, coupled with the need for greater awareness and understanding of their benefits among professionals and policymakers. Overall, the research underscores the potential of IBTs in revolutionizing the South African construction industry, emphasizing the need for strategic policy reforms and proactive measures to foster their widespread adoption in self-build typologies. The study began with a literature review to explore the current perceptions of IBTs in both professional and end-user communities. In the second phase, questionnaires were administered to IBT manufacturers. Finally, a specific IBT system was selected based on further research and assessment of its suitability for self-build architecture in a specific typological context.

### Keywords:

Housing challenges, Innovative Building Technologies (IBTs), self-build practices, regulatory context, disassembly, self-build urbanism, citizen empowerment.

# Glossary of Terms

## I. Innovative Building Technologies (IBTs)

Innovation in building technologies refers to the non-conventional and non-traditional nature of the products or systems registered with the overseeing body (Agrément South Africa). These systems are not assembled according to conventional building procedures and practices and, therefore, need to be overseen by a different set of guidelines than those found in the South African National Standards (SANS). The building technologies are either deemed to satisfy from testing done by ASA or by rational design practices conducted by a qualified and certified engineer. IBTs seek to improve the overall and long-term cost efficiency of the building, and the performance of these systems are hugely improved so that thermal conductivity, structural strength, durability, reusability, recyclability, and speed of assembly are optimal (Mbambo, S., Agbola, S., Olojede, O., 2021).

## II. Self-build Architecture

In the literature the terms self-build and owner-build are used interchangeably but, in this study, self-build will be used exclusively. In the context of this study, self-build is defined in terms of the flexibility offered to the owner to build within a framework or set of generative guidelines that are approved and in accordance with the National Building Regulations (NBR). Within the South African context, desperation is a keen driving force behind citizens constructing their own homes using found objects. This trend for informal building by the owner can also be defined as a form of self-build, but for the purposes of this study self-build will be strictly used to define participatory practices whereby the owner or resident is involved in the planning, designing and construction processes of the structure using either conventional or innovative building technologies and not found objects (Caputo, Lemes de Oliveira & Blott. 2019).

## III. Generative Codes

Generative codes (GCs) work based on a set of guidelines for city evolution to take place in an incremental manner and through user participation (JPER, 2019). Form-based codes (FBCs) are well-known to planners and reflect the form of the city currently or how it is planned to be. It is often predominantly concerned with building styles and the building's aesthetic value and contribution to the cityscape (Toker, Z. & Pontikis, K. 2011). FBCs occur in a top-down manner by planning experts and are required by regulatory planning systems. GCs are focused on step-by-step processes that encourage stakeholder engagement at every step of the project's design planning and implementation phases. The urban environment is developed according to the well-being of the residents and seeks to "improve the wholeness and coherence of the urban environment based on feedback from previous steps" (JPER, 2019). The virtues of GCs are that great emphasis is placed on "coherence, human scale, flexibility and the adaptability within the urban environment" with specific focus on sustainable development of human settlements (Toker, Z. & Pontikis, K. 2011). GCs are specifically developed and designed for a neighbourhood area or individual site to ensure that generalities are avoided and so that the design response is a process whereby planners aim to understand their environment and its inhabitants better eventuating in a better tailored solution.

## IV. Self-build Urbanism

Self-build Urbanism finds its origin in the idea of self-governance. Self-governance occurs when action is taken by non-governmental stakeholders altering their collective behaviour and organising themselves and their environment without governmental intervention. In the spatial planning milieu, this speaks to “initiatives that originate in civil society from autonomous community-based networks of citizens, who are part of the urban system but independent of government procedures” (Nederhand, J., Bekkers, V., & Voorberg, W. 2015). Self-organisation in relation to urbanism is then defined in terms of a shared, collective trend of interaction and communication with the result emerging as a new structure of goal-driven activities towards a shared vision or understanding between members of the collective. This occurrence is triggered by an event or in response to a system change (societal concerns) and elicits interaction; it also occurs when trustworthy relationships amongst stakeholders exist, in other words, there is a great social capital within the neighbourhood or region (Nederhand, J., Bekkers, V., & Voorberg, W. 2015).

## List of Abbreviations

| | | |
|---|---|---|
| SA | - | South Africa |
| ASA | - | Agrément South Africa |
| SAIA | - | South African Institute for Architects |
| IBT | - | Innovative Building Technologies |
| CTB | - | Conventional Building Technologies |
| NHBRC | - | National Home Builders Registration Council |
| DSI | - | Department of Science and Innovation |
| DHS | - | Department of Human Settlements |
| NHF | - | National Housing Forum |
| FBC | - | Form-Based Codes |
| GC | - | Generative Codes |
| SANS | - | South African National Standards |
| NBR | - | National Building Regulations |

## 1. Introduction

This study seeks to identify opportunities for symbiosis between Innovative Building Technologies (IBTs) and their implementation in a self-build architectural typology. The purpose of the study is to identify which IBT system or product, if any, is best suited to a self-build typology in South Africa. The system will be identified through the circulation of a survey and a question list and an additional in-depth interview with the manufacturers included in the study. To fully understand the appropriateness of a self-build typology and the related regulatory requirements for such a typology, one first needs to understand the current socio-economic environment within South Africa.

The paper is structured as follows, as illustrated in *figure 1*: Chapter 1 will provide background and a context description of the three realms for consideration in the paper, (1) the context within South

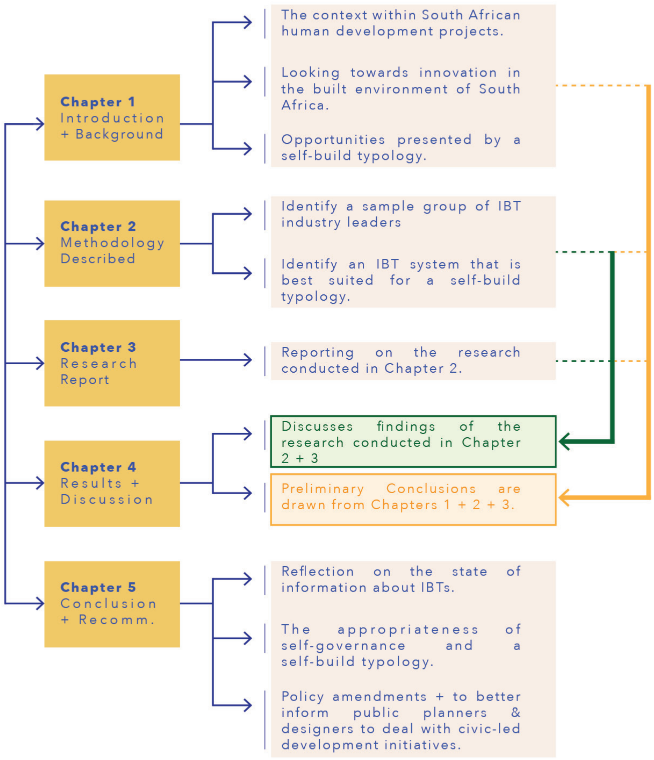


*Figure 1: Diagram to show the structure the study report will follow (Author, 2023).*

African human development projects, (2) looking towards innovation in the built environment of South Africa, (3) opportunities presented by a self-build typology. Chapter 2 describes the methods followed for the investigations executed within the IBT industry presently available in South Africa. In this chapter, the process followed to identify a sample group of IBT industry leaders is described and how a further filtering process will be conducted to identify an IBT system that is best suited for a self-build typology. Chapter 3 reports on the findings of the research conducted in Chapter 2. Chapter 4 discusses the results of the research conducted in Chapter 2 and 3 and preliminary conclusions are drawn between the literature of Chapter 1 and the investigations conducted in Chapter 2 and 3. In Chapter 5, the paper will conclude with a reflection on the state of information surrounding IBTs, the appropriateness of self-governance and a self-build typology and how policy amendments can better inform public planners and designers to deal with civic-led development initiatives.

Supplementary information will be gathered to understand the appetite of the construction industry for the use of IBT systems in South Africa, what the regulatory networks require are for IBT manufactures, the dilemma of public perception when it comes to using non-conventional building technologies, and lastly the study aims to identify a set of criteria that could be used to identify IBT systems that can support a self-build typology. The research methodology will follow a mixed method approach focusing on both qualitative and quantitative aspects of the data to be collected. A literature review is used to establish the current state of information about IBTs, self-build architecture and how municipal legislative accommodations could be amended to acknowledge self-built buildings as lawful structures requiring local governmental service provision. A preliminary online survey will be conducted with IBT manufacturers, and a more detailed and refined interview question list will be sent to selected IBT manufacturers and followed up by a semi-structured interview for more specific discussions. This process was followed to gain a sample group within South Africa of the available IBT systems and products that are both Agrément certified and currently active.

*Figure 2* maps how the study's research question will be investigated and answered. The question is multifaceted with many factors needing to be considered, the flow diagram shows how the identified subjects within the study relate to one another and how they will be unpacked in research.

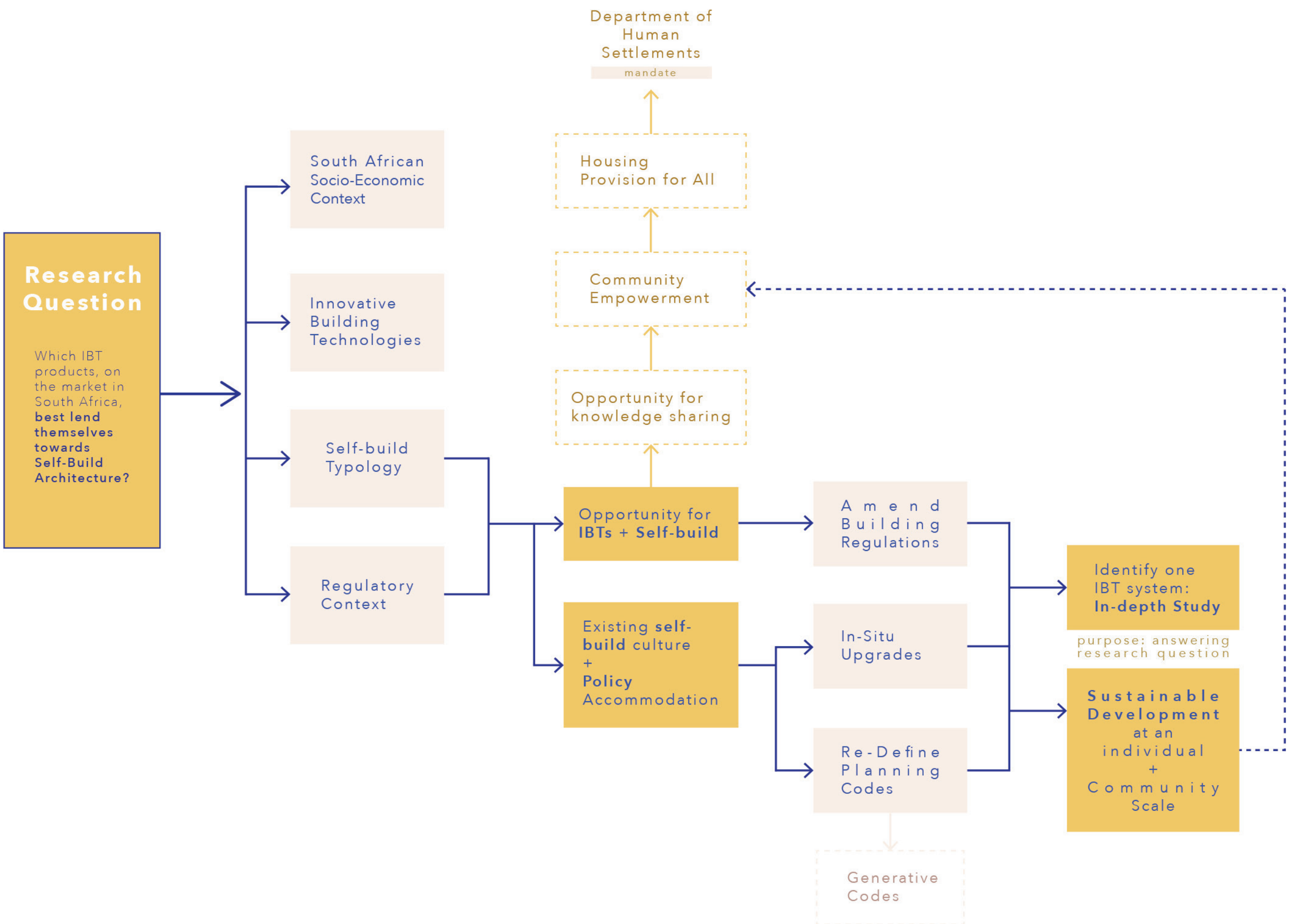


*Figure 2: Represents the connections made between the themes discussed in the study (Auther, 2023).*

## 1.1. Human settlements with the South African context

In South Africa there are numerous opportunities for infrastructural development within the socio-economic sectors namely, housing, education, income (job security), community safety and social support especially within the low-cost, government-facilitated, and informal construction sectors (Mahachi, J., 2018). A delimitation of this study is that it is focusing on the development context of government-driven social infrastructure and development of low-cost housing and town development schemes. Consideration is given to strategies that could ensure integration of IBT systems with self-build activities and how this relationship could help streamline government's efforts in providing safe and equitable housing to all. The country is faced with a shortage of appropriate and operational infrastructure (buildings, roads, sanitation systems, etc) and the necessary skilled labourers to execute construction projects readily (Mahachi, J., 2018). As a result, the Department of Human Settlements (DHS) declared that new methods, incorporating science, technology and innovation will be implemented in housing schemes to confront the accumulated infrastructural predicament facing the country (Mbambo, S., Agbola, S., Olojede, O., 2021).

The National Housing Forum (NHF) was established during the formulation of the "South African Housing Policy" before the first democratic elections in 1994. It is a "multi-party non-governmental negotiating body" with 19 members representing various sectors, including business, community, government, development organizations, and political parties. The NHF's primary focus is on housing and urban development plans in South Africa, with the principal objective of ensuring the realization of the constitutional right to adequate housing for all (SERI, 2018).

On a national housing scale, indicated by calculations done in 2020, South Africa's housing backlog sits at 2.4 million houses still needed to be built at that point in time. As a result, most citizens, eligible for subsidised governmental housing, live in informal settlements while awaiting a house or housing grant (Mahachi, J., 2018; Adetooto, J., Windapo, A., Pomponi, F., 2022). The Department of Provincial and Local Government (DPLG), to lower these figures, implemented the Urban Regeneration Plan (URP) in 2001 in eight specific poverty-stricken nodes across South Africa. The URP aims towards pooling governmental resources to fast-track infrastructural development meant to improve the quality of life for all South African citizens while breaking the cycle of underdevelopment in urban areas (National Department of Housing and Department of Provincial and Local Government, n.d.). The South African government has gazetted the housing issue as being pressing and of immediate importance and yet national, provincial, and local municipalities have not risen to the task of improving these conditions (Mahachi, J., 2018). Priority towards public, social, and cultural buildings have been low as well.

According to Rauws (2016), the current construction environment is dominated by project developers, social housing development companies and municipal governments dictating what is built, where it is to be built and by whom it will be built. The 'red tape' becomes a strong opponent to try and overcome.

In the global North, housing is often categorised as a "sub-sector of the construction industry" while in the global South, 'housing' becomes a verb, an activity of "meeting basic needs for shelter" (Miles, M., 2013). Miles (2013) postulates that we find ourselves in a situation where urban development has been handed over to the private sector in a "political and economic climate of neoliberalism", but this leaves the user, current homeowners, and aspiring homeowners, to ask what alternatives exist to market-led development and newly built homogenous units in housing developments.

Within this reality, the country's citizens take part in construction activities in their own capacity.

A house is, in many households across the world, the biggest investment a family will make in their lifetime (Mbambo, S., Agbola, S., Olojede, O., 2021). Citizens participate in owner-construction practices to provide themselves with shelter when the government-led initiatives for basic housing provisions fail to do so. This is why the task of ‘housing’ is regularly undertaken by the users in their own capacity. This results in the ever-present growth of informal settlements surrounding most urban centres (Miles, M., 2013). These owner-constructed structures often lack adherence to building regulations, resulting in unsafe and unhealthy living conditions. The resulting structures are often built using found objects such as metal panels or components, plastic, wood, and corrugated iron which are often unsuitable and combustible (Chenwi, L., 2012).

In many countries and many postulations later, the consensus has been reached that a region-specific strategy needs to be developed to ensure that existing social housing developments, current informal settlements and any new housing development schemes propagate healthy environments, dignity and safety for the residents living there. Studies into the best course of action for addressing growing informal housing areas provide mixed responses and approaches. The most common aspect addressed in the literature is the high initial capital inputs required for new housing developments or *in-situ* upgrades of existing informal settlements. The need for country-wide municipal intervention in housing provision schemes is equally as high as the cost of intervention (Mahachi, J., 2018; Chenwi, L., 2012). The financial weight of the housing crisis serves as a possible reason why very little progress has been made.

From the above discussion, it seems that housing, like any other sector of the construction industry, is fabricated according to “prevailing economic, social, political and cultural imperatives” (Miles, M., 2013). This study hypothesises how South African building regulations and planning policies could be altered to accommodate for the existing culture of semi-unregulated building practices that occur spontaneously throughout the country, across economic statuses and geographic regions. The question we are left to answer is what the implication would be if IBT systems were to be included alongside a self-build typology to aid in democratising the housing construction industry in the country?

## 1.2. Understanding the Innovative Building Technology Environ

Architectural history has shown that brick masonry has occupied its primary position as the building module of choice in the construction industry. As a result, when faced with a new architectural endeavour, the modern-day professional team intuitively leans towards the conventional and versatile clay brick. South Africa, not unlike the rest of the world, has clay masonry structures occupying most historic regions in the country. This has contributed to public and professional perceptions that Conventional Building Technologies (CBTs) are still preferential in construction projects as opposed to implementing new IBTs that are on the market today.

Another side to the IBT discussion is what effect these products and systems have or will have on unskilled and semi-skilled labourers’ opportunities and likelihood of finding work. The need for job creation coupled with the great infrastructure and development shortcomings in the country, sets the stage for great innovation opportunities. Using the humble clay brick allows the built environment to improve infrastructure without too much difficulty nor major project delays. Unfortunately, focus is placed on infrastructural needs at the expense of developing new and innovative materials that may outperform CBTs and have greater building life-cycle properties (Mahachi, J., 2018). The issue, as illustrated in the literature, is twofold; firstly, precedent projects using IBTs are scarce or limited, remote or under documented and, secondly, sufficient priority for enquiries into further development of IBTs is lacking.

To further understand the milieu surrounding IBTs and CBTs the following four aspects will be discussed in more detail: (1.2.1) the regulatory context within South Africa, (1.2.2.) end-user perceptions of IBTs, and (1.2.3.) the slow uptake of IBTs in the private construction sector.

### 1.2.1. Regulatory Context

This study is conducted within the realm of the Department of Human Settlements (DHS) and their relationship with Agrément South Africa (ASA) and the National Home Builders Registration Council (NHBRC).

The role of government in regulatory policies has an enormous impact on innovation in the construction industry. In the context of IBT led housing projects, as promoted by the NHBRC, the goal is to augment the insufficient "housing stock" especially in the sector of affordable housing constructed using CBTs. For this to occur at the scale that is required in South Africa, a shift in policymaking needs to occur (Department of Housing 1995:1376). This shift requires policy amendments as well as an awareness-making campaign to educate those in positions of leadership on how these IBT systems work, what specifications are required when writing tenders for governmental developments, and how to compare different systems when assessing applicability for project application (geographical region requirements, if the project is remote and requires extensive transportation, the scale of the development, to name a few factors).

The role-players in the legislative environment dealing with IBTs are:

***The Department of Human Settlements:***
The DHS "has a mandate that is integral to the effort of the government to change the lives of South Africans for the better. This includes transforming the apartheid spatial, land and development patterns of social and racial exclusion" (Department of Human Settlements, 2017). The department was established after 1994. The department's earliest version can be seen in the Freedom Charter* of 1956. The clause says, "there shall be houses, [and that] security and comfort are the founding base [of] the department." South Africa's Constitution (1996) also states that access to housing is a basic human right for all and that the government must ensure [this]." The DHS has the mandate to provide facilitation of a "sustainable housing development process" this includes laying down general guidelines that are applicable to the housing industry in all spheres in government. According to Section 5(2)(b) of the Housing Act (19/1997) the roles and responsibilities of the national, provincial, and local governments are defined according to housing developments and to "provide for the establishment of a South African Housing Development Board."

***The Department of Science and Innovation:***
The primary objective of the Department of Science and Innovation (DSI) is to "boost socio-economic developments" in South Africa by facilitating research programs and enabling environments for innovative thinkers. Through the DSI's programs, "administration, technology innovation, international cooperation and resources, research development and support, and socio-economic innovation partnerships" and all other supporting entities are taken into consideration (Department of Science and Innovation, n.d.).

***Agrément South Africa:***
The core responsibility of the governing body of ASA lies in assessing and verifying the technical



* The Freedom Charter of South Africa is a historic document adopted in 1956 by the Congress of the People. It outlines the aspirations of the people for a democratic and non-racial South Africa, calling for equality, land redistribution, and an end to racial segregation and discrimination. The Charter played a significant role in shaping the country's path towards democracy and freedom.

attributes of “non-standardised construction-related” systems and products which don’t fall under the SANS (National Department of Public Works and Infrastructure, n.d.). The ASA is South Africa’s regulatory body established by the then Minister of Public Works in 1969 (National Department of Public Works and Infrastructure, n.d.). Currently, ASA falls under the jurisdiction of the National Department of Public Works and Infrastructure (NDPWI) and is categorised as a “schedule 3A public entity under the Public Finance Management Act.” ASA was established under the Agrément South Africa Act No. 11 of 2015 (National Department of Public Works and Infrastructure, n.d.). One of the mission statements put forth by the organisation is that they aim to promote and support innovation in the building industry that can alleviate the socio-economic underdevelopment in some of South Africa’s poverty-stricken areas. ASA further states that they aim to assist policymakers to minimise the perceived risk involved in implementing non-standardised building technologies.

***National Home Builders Registration Council:***
The other governing body that has a stake in the government’s social housing provision schemes is the NHBRC. The NHBRC considers itself as the protector of the housing consumer while performing regulatory activities concerning the home building environment. This is achieved through promoting “innovative building technologies, setting home building standards and improving the capabilities of home builders” (National Department of Public Works and Infrastructure, n.d.). The council does not participate in the development of IBTs, nor do they advertise specific IBTs. The council aims to improve visibility and accessibility in the market for IBTs. The body is overseen by the DHS and works closely with ASA. Systems first require an active ASA certification before they can apply for NHBRC endorsement and be implemented in governmental housing schemes or private free-standing housing projects.

The overseeing body structure in South Africa is complex and many departments have supervisory mandates over many common governing bodies. The Department of Public Works and Infrastructure is the ‘umbrella’ overseer of the other departments and bodies mentioned earlier.

### 1.2.2. IBT User Perceptions

In 2019, the NHBRC conducted a national survey to understand the consumer and stakeholders’ perception of IBT products and systems currently produced in South Africa. The purpose of this inquiry was to determine what the possible barriers are in the low uptake in IBTs in the South African construction industry. Further investigation into which factors influence consumer perceptions of satisfaction or dissatisfaction were conducted, whether IBTs are accepted or not by the public and the professional industry, what the local and global trends are for the implementation of IBTs, and to understand how the government aims to implement and promote the use of IBTs in their housing provision projects. The survey had four points of inquiry; (NHBRC, 2019).

1. Drivers for construction innovation in South Africa,
2. Consumer satisfaction, dissatisfaction, and level of IBT acceptance,
3. Highlighting case studies, and
4. Situational analysis of low-income houses in South Africa.

The NHBRC study started by considering key participants in the construction innovation industry: IBT manufacturers, contractors, and clients. Clients, according to the study, have an idiosyncratic ability to insist on a higher level of innovation from their construction team for a required better building life cycle and performance, a higher standard of work and overall improved project flexibility (NHBRC, 2019). Production processes in the innovation sector are often hindered by intermittent projects as they are often once-off in nature or tailored to a unique project (NHBRC, 2019). Not only does this have a negative impact on the production costs of reigniting factories periodically but it further hinders the transference of knowledge in “organisational memory” within the industry. The recognition of communalities in projects with similar or identical requirements are therefore lost and cannot be used to build a core understanding or frame of reference when implementing IBTs.

### 1.2.3. Limited application of IBTs in the Private Sector

A significant portion of the literature highlights the importance of industry relationships between the manufacturer, assemblers, and the installers of the IBT systems and that these relationships are integral for the facilitation of “knowledge flow[s]” (NHBRC, 2019). Bettering these relationships can be seen to improve the IBT integration processes and awareness amongst industry professionals about the opportunities proved by IBTs. Another discussion point should be the process of procurement associated with IBTs, the decision to include IBTs in a project should be made right from project inception to allow the design team to account for the technical requirements of the selected IBTs to be factored in. This aspect of the project is often challenging for construction firms as they face difficulties in accessing up-to-date technical information about the systems. Industry professionals are hesitant to adopt IBTs and other non-traditional processes due to the industry’s lack of familiarity and understanding (NHBRC, 2019). In addition, experienced labour using or installing IBT systems is still scarce (NHBRC, 2019). For newer IBT companies, the initial start-up costs involved in establishing a manufacturing plant and keeping production outputs high is still at a significant cost especially when compared to a CBT manufacturing plant producing clay bricks, for example. It is only when a steady flow of construction need is achieved that the manufacturing cost of IBTs become comparable to many CBT’s costs of manufacturing (NHBRC, 2019).

IBTs currently fall outside the ‘normal scope’ and level of awareness for many Architectural, Engineering and Construction (AEC) professionals and training programs often fail to provide these professionals with exposure or even training on how these alternative building technologies work. Therefore, a requirement exists within the AEC industry to increase exposure to the sector of construction innovation.

### 1.2.4. Preliminary conclusion: the IBT Environ

In conclusion, it is necessary for an exhaustive investigation to be conducted into the best and most applicable relationship present between each IBT product or system and which typological application they are best suited to. There is much uncertainty within the AEC industry about the possibilities offered by IBTs and further access to technical information is lacking. IBT professionals could consider having data packs detailing their system’s typical construction details available for easy download by professionals aiming to implement IBTs in their construction projects. This increased access to information on IBTs will help in demystifying the industry and eventually aid in the increased market uptake of the innovative systems. In terms of the regulatory context governing IBTs, the overseeing structures have been created by government, but more could be done from their side to promote the use of IBTs for both public and private developments.

## 1.3. Self-build architecture as a proposed typological solution

Considering the ever-growing need for infrastructure in South Africa, speculative building construction methods could relieve much needed pressure in housing and social architecture developments. The previous section discussed the current state of policy structures and networks, and where IBT systems are positioned in the larger aspiration to alleviate the infrastructural needs within the country. A self-build typology is proposed as a potential solution for national, provincial, and local governments to address the significant infrastructural backlog. This approach involves a decentralized system where users actively participate in the construction and maintenance of the buildings they occupy.

Self-build architecture is a multi-faceted concept (Miles, M., 2013). The self-build alternative offers urban dwellers the opportunity to provide shelter for themselves in a way that is not linked to market-led developments which are often largely governed by the private sector (Miles, M., 2013). The concept of owner-led participation in the planning, design and construction processes involved in a project is of central importance. Community engagement and involvement in designing of neighbourhoods offers a new opportunity for dignified and individual empowerment practices to occur within the AEC industry. The rapid, albeit often uneven, growth in cities in the global South alongside the acknowledgement that informal settlements offer an unconforming form of ordering in densified living areas means that there is a wealth of lessons to be learnt in terms of economic and social benefits (Miles, M., 2013). Self-build architecture is grounded in self-governance which sees an individual operating within a “frame of agreed vision,” coordinating choices with other self-builders and allowing for the creation of permanent mechanisms of management (Caputo, Lemes de Oliveira & Blott., 2019). Self-build architecture looks to be an attractive alternative to users who possess the time, the inclination, access to resources and the necessary skills to undertake such an endeavour (Miles, M., 2013). An amended model for policy and local planning frameworks should be considered to allow local community members the ability to shape their neighbourhoods and further urban development according to their needs, while still meeting the standards for structural stability and safety accounted for in SANS and NBR design standards.

In South Africa, not unlike elsewhere in the world, informal settlements are seen to challenge the “urban order” of cities. There are a few who realise the possibility of these owner-constructed and self-governed settlements to alleviate the need for sustainable urban development because of their lower construction costs when compared to conventional housing schemes (in both the public and private sector). Under the looming threat of the climate issues we face, there is a far greater need for innovation in the development of densified urban and suburban areas, a way for us to live more responsibly within the shrinking habitable areas (Miles, M., 2013).

### 1.3.1. Regulatory context and accommodations for a self-build reality

Precedent projects, on a neighbourhood scale, for self-build developments predominantly exist in the global North in countries such as Germany, the Netherlands, the United Kingdom, and France (Caputo, Lemes de Oliveira & Blott. 2019). Self-build typologies start to question the role of a centralised and standardised authority in local planning frameworks, building regulations and spatial definition codes. A self-build typology requires that there is a cultural shift in planning frameworks and building regulations, but it is a shift many professionals, elected representatives and many dwellers are hesitant to accept (Miles, M., 2013).

The introduction of South Africa’s democratic government came with the implementation of the

Constitution of the Republic of South Africa (the Constitution) in 1996. Consecrated in section 26 of the Constitution is the “right of access to adequate housing” and this section is the most frequently litigated and contested “socio-economic right” in the South African Constitution (SERI, 2018). Numerous legislative amendments have been made since the finalisation of the Constitution twenty-seven years ago. A specific piece of legislation relevant to this study, is the Housing Act 107 of 1999 (the Housing Act) and how this Act has contributed to the improvements being made in the sector of informal settlements. Government programmes have been set up and are aimed specifically at addressing the “challenges posed by informal settlement upgrading” (SERI, 2018) and whether the development programmes should be aimed towards *in-situ* upgrades or demolition-and-rebuild projects.

The Housing Act 107 of 1999 (The Act) is the primary legislation to be consulted when dealing with housing in South Africa. The Act deals with housing provisioning on a national scale and provides a set of principles to be followed during housing developments. The Act is concerned with housing developments in all spheres of government and across all provinces, it defines the roles national, provincial, and local governments play in respect to housing schemes, and it outlines the procedures followed to offer financial assistance for national housing programmes (SERI, 2018). The Act (section 2(1)) further provides that the state “must ensure that housing developments offer as wide a choice of housing and tenure options” as possible in each development scenario, it states that these housing programmes be “economically, fiscally, socially and financially affordable and sustainable,” that administration activities are kept transparent, accountable, and equitable, and lastly uphold the condition of practice of good governance (SERI, 2018).

The National Housing Code (NHC) contains the bulk of the legislation pertaining to housing. The following aspects are not covered in The Act: main regulatory framework principles, how policy choices are to be made and how the rules for implementation are to be set out - but rather clearly stipulated in the NHC (SERI, 2018). When it comes to the informal settlements’ discussion about *in-situ* upgrading or processes for resettlement, the NHC diverts to the Emergency Housing Programme (EHP) and the Upgrading of Informal Settlement Programme (UISP) for further and more specific guidelines (SERI, 2018).

The urban policy of the ‘new’ South Africa, after 1994, has diverged in two directions; the first recognising the benefits of self-build housing to the extent that government has sponsored *in-situ* improvements in regions, and secondly, the creation of policy aimed at clearing all informal settlements by the then deadline of 2014*. The two directions are completely incompatible and have caused a standoff within the government itself (Miles, M., 2013).

Under the instruction of the NHC, the UISP specially provides for municipalities to apply for funding within the provincial budgets to “redevelop informal settlements by incrementally providing occupiers with infrastructure, tenure security, and access to basic services in an inclusive and participatory manner” (SERI, 2018). The EHP is more limited in its application within the context of this study. EHPs are implemented to offer temporary housing relief from emergency situations or conditions (i.e., threat of eviction whether lawful or not) by providing alternative accommodation in the short term. UISPs focus on short- and long-term municipal engineering services and infrastructure. The issue of tenure security is not considered under the EHPs because the intervention is meant to be temporary but in the case of UISPs tenure security is a central component. It is achieved through “a variety of tenure arrangements that are to be defined through a process of engagement between local authorities and residents” (SERI, 2018). The UISP strongly prefers *in-situ* upgrades to minimise the disruptive effects of relocation or the effects of major government intervention. All efforts, within the context of the informal settlements as defined in the UISP, are aimed at keeping the occupiers on

*The piece of legislation in South Africa that dictates the creation of policy aimed at clearing all informal settlements by the then deadline of 2014 is the “Breaking New Ground” (BNG) housing policy. The BNG policy was introduced in 2004 by the South African government with the goal of addressing housing challenges and providing access to housing for all citizens, including those living in informal settlements. However, the goal of clearing all informal settlements by 2014 was not fully achieved, and the housing backlog continues to be significant in the country.

the land they are currently inhabiting. *In-situ* upgrading of informal settlements is preferential as the action taken by government to acquire the land (by purchasing or expropriation), rehabilitate the land and install service networks allows for community rejuvenation programmes to occur. This suggests that occupied land "could be purchased or subdivided to develop UISP projects" for residents of informal settlements (SERI, 2018).

In application, this is not the reality of the situation. There is a general lack in the application of UISPs, firstly, because there is an "institutional and bureaucratic framework" requirement for state-subsidised projects to be built in areas that are bare and undeveloped and this is how it is currently developing. *In-situ* upgrading processes are new and foreign in concept to many government officials and, as a result, mean that this form of upgrading is ignored. Secondly, sub-sections of government feel that many functions of the UISPs are "in conflict with fiscal frameworks prohibiting wasteful and inefficient expenditure" (SERI, 2018). The incremental nature of *in-situ* upgrading programmes are therefore avoided and local and provincial governments instead focus attention towards "fully formalised" housing developments (SERI, 2018).

A general shift in thinking needs to occur. The parameters whereby UISPs can or should be implemented need to be clearly defined to limit misunderstanding amongst government officials. Amendments to building regulations could facilitate new construction processes to emerge and give rise to new building forms and typologies. An organisation such as the Johannesburg Inner City Partnerships (JICP) can be given stewardship over a self-build pilot project to assist in the facilitation of sustainable community governing mechanisms that will ensure the sustainability of such a project.

Currently, self-build projects are familiar in the discussion of backyard dwellings. In the informal housing sector, residents often participate in constructing their own additional dwellings into the erven of existing housing developments and as a result create higher density living environments. This densification trend is not uncommon in South Africa. These types of densified construction projects are completed under varying construction qualities and through an assortment of building practices. Densified housing environments are evolving under the labouring hands of the current residents seeking to solve the need for shelter in their personal capacity. This can be attributed to the length of time qualifying citizens await a government issued or subsidised house. The City of Cape Town (CoCT), for example, decided to contravene the eradication declaration of informal settles issued by the government and, instead upgrade informal settlements and backyard dwellings. This was achieved by providing basic services including access to running water, drainage, and power lines in a sustainable and equitable manner. This step taken by the municipality starts the process of legitimising the practice of informal building regardless of national policy. The CoCT furthermore has taken steps as a local government to invite tenders for work, carrying out surveys, and drafting business plans for pilot projects of a similar nature throughout the metro. The goal is for 'incremental improvement of the entire living environment' while ensuring that upgrades "reflect the needs identified by the communities themselves" (Miles, M., 2013).

### 1.3.2. Planning frameworks require reconsideration.

The aspiration for a self-build typology to alleviate the housing backlog requires a revised and reimaged set of design and planning guidelines. The adoption of generative codes (GCs) has been investigated by countries like the Netherlands, as a possible starting point to provide a "non-prescriptive approach to planning." Within the South African housing context further research is required as the accommodations made by GCs are predominantly experimented in the Global North (JPER, 2019). GCs can be described as "fertile ground for experimentation" for self-build as they act as “yardsticks to appraise the effectiveness” of self-build projects (Caputo, Lemes de Oliveira & Blott. 2019). This sub-division of codes takes many socio-economic factors such as financing, ownership, management, material sourcing and ensuing changes to the original design into account. The goal with GCs is to develop a specific set of neighbourhood-based guidelines that are generated for a precise situation, context, and considers situational concerns within the area. This is to say that a specialised set of GCs are required for each dedicated self-build area because the need is for guidelines to be more in-tune with local requirements than the standardised codes provided in national building regulations and planning frameworks (Caputo, Lemes de Oliveira & Blott. 2019).

The process of planning neighbourhoods and urban areas require certain planning practices and codes to be put into use, three types have been identified namely, Zoning Codes, Form-Based Codes (FBCs) and GCs. The most well-known coding system is the zoning-based codes (Euclidean Zoning Codes) and have been in use by planners since before the 20th century to determine development patterns (JPER, 2019). This type of planning code often facilitated the sprawling patterns that emerged in settlements surrounding big city centres. In contrast, FBCs work with the relationship between “building facades and the public realm,” the massing of the building in relation to other buildings, and with the gradation of scales from types of streets and blocks (JPER, 2019). Architectural language, landscape treatment, universal signage and environment conservation principles can also be included in the FBCs. Walkability, transit-friendly and fostering a community character are the key objectives of FBCs (JPER, 2019).

In contrast, GCs are a regulatory planning process focused on development through evolution in an incremental manner. Stakeholders are engaged and drawn into the process at every stage to ensure planning is appropriate, coherent and what the community really needs. GCs ultimately ensure that regional flexibility and adaptability is considered and included in the planning right from the outset of the process (JPER, 2019). The well-being of users is a chief informant alongside the promotion of sustainable and ethical building practices. This is achieved through ecologically sustainable building and ensuring social justice for community members as the driver behind using GCs in self-builds particularly (Caputo, Lemes de Oliveira & Blott. 2019).

New planning codes will ensure that assumptions relating to the urban form and human activities can be adapted to contemporary society and its movement patterns (Alexander, C., 1979). There is a need for more accommodating infrastructure and more dynamic open green spaces for recreation and social activities within neighbourhood designs (Alfasi, N & Portugali, J., 2007). Ensuring that self-builds are recognised in this new form of planning codes will ensure that these buildings will be classified as legitimate and, therefore, be serviced and maintained by local authorities. Self-build architecture does in fact face some challenges for owner-led development and construction, this being in terms of access to resources, appropriate skills, and knowledge alongside the need for supportive policy and regulatory frameworks (Caputo, Lemes de Oliveira & Blott. 2019).

### 1.3.3. Architecture for Disassembly and a Self-Build Typology

Once the regulatory context is considered, one needs to consider and articulate the activities that encompass self-build projects. Architecture for disassembly deals with the transfer or reduction of the embodied energy housed in existing buildings. A building’s life cycle can be divided in two categories, its economic life and its physical life, the latter being much longer than the former (Crowther, P., 1998). The principle of design for disassembly is concerned with the levels of obsolescence involved in the decommission of buildings for either upgrades, replacement, or modernisation practices. Current building design practices and sourcing of materials is done driven by the goal to achieve economic return with the predetermined period of investment. A time arises for any building to undergo a transition towards the end of its economic life cycle, this historically being demolition. Potential reasons for this sequence of events are listed below.

1. “Locational obsolescence” when the buildings function is inappropriate for its current location,
2. “Functional obsolescence” when the society no longer has a need for the building’s function,
3. “Technical obsolescence” where the building no longer adheres to expected performance requirements,
4. “Physical obsolescence” when the building or its components “have fallen below acceptable standards of safety” due to degradation,
5. “Fashionable obsolescence” simply when the building no longer meets the accepted standard of style and contemporary aesthetics (Crowther, P., 1998).

Once one form obsolescence is reached, the building experiences a form of demolition. Factors influencing the level of material wastage a building undergoes once it is facing demolition can be attributed to difficulty in disassembly and separation of the components used in the building’s construction. This results in high material wastage rates and the increases the uncaptured potential of the embodied energy housed within a building (Crowther, P., 1998). Often if disassembly and separation is achieved it is the result of an extremely time-consuming procedure and results in the entire venture being inefficient and not economically viable. Ultimately, the aim should be to strategically design for disassembly as it allows for more environmentally sustainable building systems to be implemented. Design for disassembly comes down to one idea, “overcome or reduce obsolescence” and this extends to material selection and how these materials are assembled. Assembly, disassembly, transport, and handling of specifically lightweight materials means more opportunity to reuse and recycle these materials. The term “economy of material” calls for prudent application and implementation of materials.

Low-tech connection points are another technique implemented in designing for disassembly. Assembling a low-tech joint also means that the need for energy and additional material is reduced, making it more efficient and effective. This type of low-tech system means that minimal effort and a lower level of skill is required to install and disassemble these systems in a short period of time, and this helps to avoid locational obsolescence (Crowther, P., 1998).

Flexible systems are required to be designed within an open system to allow the system’s assembly to be executed in more than one way and solves functional and technical obsolescence. Alternate arrangements within the system’s components means that a disassembled building can be reassembled into a new building serving a new purpose within the same context. In this way the building’s locational and functional obsolescence can be avoided in the short- and long-term. An open system further allows for incremental expansion of the building to occur.

Designing for building disassembly ensures that a building’s life cycle is extended in a social, economic, and environmentally sound way. Crowther (1998) identified a few characteristics to aid in reducing building’s obsolescence:

- Material choice: light weight and climatically appropriate
- Parallel building systems: main frame and envelope sub-structure
- Low-tech material and joint connection points
- Open building design systems
- Modular construction techniques
- A limited number of different standard parts

- A detailed sequence for building system disassembly
- Disassembly at all levels without damaging initial components.

This list is not exhaustive but a mere indication of the potential for designing to reduce building obsolescence. The literature indicates a further potential for buildings designed for disassembly along with low-tech connections to be applicable in a self-build typology. Open system designs consisting of various components predisposed for disassembly practices could mean that building regulations can be amended and made more accessible to the layman. Construction can be executed by semi-skilled labour with minimal professional intervention.

The literature indicated that there needs to be a clear distinction in the assembling procedure of the system and the system's performance features to be able to establish the most appropriate typological application of the IBT system. To establish which IBT products, on the market in South Africa, best lend themselves towards self-build architecture it is important to formulate a list of systems that can efficiently be disassembled. A disassembly feature is not enough for a self-build typology, the system also needs to be able to be reassembled post disassembly.

### 1.3.4. Self-governance and Spatial Planning

According to Miles (2013) the viability of self-build architecture is at root a political issue and the degree to which the government is inclined towards neoliberalism. For a self-build typology to truly become a viable alternative, planning decisions need to be democratised and not be predominantly disseminated by capitalist market-driven informants. Self-build settlements in the UK's Ashley Vale and Coin Street are self-governed by residents themselves or by a local voluntary group. This type of co-ownership of neighbourhoods is hypothesised to lead to more sustainable and socially owned cities in the future.

The ideology of self-governance is based on research done into complexity sciences (Rauws, W., 2016). This branch of science is grounded on the idea of evolution through phenomenological exchanges, it rejects Newton's conceptualization that the world is "based on reductionism, determinism and predictability." Self-governance through the lens of complexity science accounts for the "spontaneous formation of patterns or structures" at both a local and global level. To fully understand the concept of the 'self' in self-governance means to associate 'self' with semi-planned, less rigid, and the spontaneous emergence of activities within a shared community goal (Rauws, W., 2016).

Civic-led developments on an urban and suburban scale can be phased as activities and actions involving "a transfer of content and process-related responsibilities from public authorities towards the individual citizen or a citizen collective" (Rauws, W., 2016). Complexity sciences appreciates that "systems continuously co-evolve" and are not produced in a vacuum but rather under the influences of contextual and internal prompts. The goal, of a self-build typology, is to trigger the formulation of alternative frameworks in neighbourhood-scaled developments. GCs serve to guide self-governing practices by introducing internal coordination practices which favour the incremental urban development of the cities and suburban fabric (Rauws, W., 2016). For facilitation to occur within self-governed urban developments, planners need to act as the interface between optimistic project participants, their goals and aspirations and the current rigid planning policies instilled by local governments (Rauws, W., 2016). Planners and designers offer insight in identifying potential synergies between project participants and the goal set by municipalities.

### 1.3.5. IBTs in a self-build typology

In attempting to introduce self-build as a new typology, it is suggested that IBT innovators should design to offer a faster solution to the slow-turning wheel of governmental infrastructure deployment (Mahachi, J., 2018). Self-build activities require the construction process to be simplified at the assembly stage by carefully considering the joinery of their systems. The joints need to be low-tech and without the need of machine intervention to assemble components. By ensuring the joint systems of the IBTs are uncomplicated and can be fixed manually, ensures that semi- or unskilled labour could be engaged to participate in the construction process. The prefabrication processes undergone by most IBTs during manufacturing ensures that many IBT system are modular and will handle with relative ease when brought to site. Another proponent of self-build systems lies in their ability to be disassembled and reassembled in a cyclical process and eventually be recycled when it reaches the end of the building's life cycle. Multiple factors influence the appropriateness of using a selected IBT in a self-build intervention; the local environmental context, local policy and regulations, availability of local semi- or unskilled labour, material accessibility, availability of transport networks and equipment required for installation (Caputo, S., et al., 2016).

## 1.4. The study's goal:

A thorough review of the available literature on IBTs in South Africa exposed an opportunity to investigate whether the typical modularity and beneficial performance characteristics of IBT systems could be applied to typology that facilitates system commercialisation and increased public accessibility. IBTs currently implemented in state-sponsored low-cost housing developments are erected under the centralised mandate of the DHS. It is hypothesised by this study that speculative building construction methods could relieve some of the much-needed pressure in housing and social architecture developments' sectors. The study proposes the introduction of a self-build building typology which uses standardised and uncomplicated IBT systems, which are commercially available, to support the government in delivering housing to residents of informal settlements.

The problem is that a limited understanding of IBTs exist within South African AEC industry and results in restricted market uptake and implementation. IBTs provide the opportunity to be used by layman in a participatory context that helps alleviate the country's housing shortage.

The study aims to answer the following research question: *which IBT products, on the market in South Africa, best lend themselves towards Self-Build Architecture?*

## 2. Methodology

This study seeks to add to the academic and practical knowledge surrounding IBTs in South Africa through engaging with informational resources available to the public and through further engagement with the manufacturers of IBT systems through surveys and semi-structured interviews. The study was conducted through a rational and systematic approach. The study considers the current building regulations in South Africa (SANS and NBR) and how amendments pertaining to a self-build typology could be integrated into policy and eventually into practical construction projects. The positions taken by the study to gain further insight into the current state of IBT implementation in the industry, the possibility for a self-build application process, policy and perception shifts that should occur were gained through a rational epistemology. This is to say that the knowledge gained in the study occurred through a process of establishing relationships between the insights of specialised people, an existing knowledge base of both the industry and IBTs and deducing where new or alternative opportunities for study lie. The researcher acknowledges that there are many variables in the study and, therefore, the outcome(s) of the study will result in many options for consideration and implementation. It is a complex and multifaceted inquiry that requires various levels of intervention, starting with addressing the end-users' perceptions towards IBTs and moving all the way to possible policy amendments on a national scale.

The research was conducted in stages as set out below:

1. *Identify currently active IBT systems listed in the ASA database, in the form of a desktop study.* Ascertaining the required background information meant consulting the ASA databases, research into the current milieu of IBTs in South Africa, identifying what qualifies a system or product as innovative, the procedure followed for ASA accreditation, extensive research about self-build architecture, and what the regulatory requirements are for this typology.

2. *Manufacturers were sent initial surveys which asked general questions* to aid the study's investigation into the current state of the IBT industry within the country. The Google surveys were broad in scope to establish a base of information and aimed for both qualitative and quantitative primary data from industry professionals.

3. *Conduct individual interviews with ASA officials and one-on-one interviews with IBT manufacturers*, it was during this phase that the researcher identified which systems available on the South African market are best suited to a self-build typology. The interview questions were compiled using the base information gained from the initial desktop study and substantiated with knowledge derived from the Google surveys. The researcher conducted semi-structured interviews with the industry professionals. The outcome of the interviews were substantiated answers provided by the interviewees and any data sheets and typical construction details pertaining to their systems.

The information gathered in this study is vast and, therefore, requires certain delimitations to be set so that the knowledge gained can be coherently communicated. The study's duration is the first limitation, it was conducted over six months and inevitably affects the level of detail the study could go into. The researcher was also faced with the issue of access to technical information, such as data sheets for the approved and active IBT systems, and the number of IBT manufacturers that did respond to the email asking for participation in the study. The study's sample space is gravely limited and affected the variety and volume of the information gathered.

## 2.1. Selection process and the Agrément Website

The delimitations of the study, as implemented by the researcher, were the selection criteria used to identify the IBT systems for further research, the type of system considered for selection (limited to a modular block), and that its manufacturing process needed to be *in-situ* or prefabricated within a factory off-site. The selection process for appropriate self-build IBT systems occurred via the ASA website, under the category of ‘issued certificates.’ A list of various IBT manufacturers, specifically in the category of ‘walling and building systems’ was sought for the study. The IBT systems under investigation in this study needed to be ASA certified, marked as currently active and under the category of ‘walling and building systems’ to be included into the sample space of the study. Specific consideration was given to modular, uncomplicated system configurations, *in-situ* applications of systems, and manufactured within South Africa. The systems that did not conform to these physical characteristics were eliminated for the purpose of this study’s aim. The self-build consideration is considered according to the definition listed in the Glossary of Terms.

The result was a very broad list of IBT systems. The aim of this study is to identify which IBT system, currently on the market, is the most appropriate for application in a self-build typology. To filter the systems, a set of criteria needed to be established, this list was determined and compiled from the literature studied in Chapter 1. The identified and required factors are as follows.

1. economic sustainability (the IBT system needs to be comparable to CBT brick and mortar construction)
2. feasibility (cost implication for small business interventions, household implementation and use in social infrastructure over short- and long-term projects),
3. the possibility for disassembly of the system (without product or system damage),
4. opportunity to reuse IBT products (like bricks being able to be reused),
5. lightweight system for ease of transportation and carrying around on-site,
6. the system needs to be uncomplicated in its process of assembly, to enable semi-skilled labourers to participate in self-building,
7. sustainable construction (supporting structure is constructed as efficiently as possible),
8. the IBT system or product needs to be manufactured within South Africa
9. opportunity for IBT application in an open design system (an open design process means that the system or product can be assembled in a variety of ways), and
10. empowerment and self-sufficiency - it needs to be human scaled and facilitate participation throughout the construction process

## 2.2. Survey Formulation

The sample space of IBT manufacturers were sent the virtual background information survey, titled IBT Manufacturers Survey (see annexure 1), to filter the larger group into a more refined set of manufacturers for the next phase of the in-depth study. The survey aimed to identify the manufacturers’ factory locations, the frequency of their systems see implementation in construction projects (greenfield or *in-situ* upgrade types of projects), what they consider the most challenging part of the IBT industry is, and their perception or opinion about which typology their system is the most appropriate to be implemented in.

## 2.3. IBT Manufacturer Interview

Eight semi-structured interviews were conducted with the IBT manufacturers to gain further insight into the systems currently available in the market. the questions used in the interviews were compiled using information gained in the google survey and additional IBT research conducted in chapter 1, see appendix 2 for the list of questions. Interviewees were identified through the initial google surveying process. The purpose of these interviews was to gain insight into intrinsic knowledge and experience within the industry that does not readily reach the users or implementers of the IBT systems (Rauws, W., 2016). Interviews were recorded for due diligence and record keeping purposes and the interview transcripts were sent back to the interviewees for verification of the documentation. The results derived from these interviews were supplemented by information collected in the literature review.

## 2.4. Data capturing and analysis

In the study, each participant was assigned a unique participant number to ensure the anonymity of their identity in the research findings. This measure was taken to comply with the approved ethical clearance documentation. During the desktop study phase, data from the ASA database was entered into an excel spreadsheet for reference when contacting IBT manufacturers for the initial Google survey. The spreadsheet included company names, contact details, the ASA accredited system names, and hyperlinks to their ASA certificates. Responses from the Google surveys were downloaded into a separate excel spreadsheet and compared for analysis.

The survey data and background research on each participating system were used to formulate questions for the semi-structured interviews. Handwritten notes and audio recordings were kept during the interviews for documentation.

All collected data and personal information in the study will be securely stored in the University of Pretoria's research data repository and platform *(https://researchdata.up.ac.za/)*. Data will be retained for a specific period and disposed of following the prescribed time frame.

## 3. Research Report

The study started with collecting background information about the environment of IBTs in the construction industry and about the IBT manufacturers currently partaking in the industry. The ASA database and the criteria listed in Chapter 2.1 was used to identify the 90 currently active IBT systems' certificate holders within the category 'wall and panelling system.' The researchers contacted the 90 certificate holders via email enquiring about participation in the study. Only 8 positive response emails were received, 34 were unresponsive and a further 48 respondents' email information was outdated and resulted in the emails delivering an error message. The 8 respondents filled out the online Google survey and indicated that they would participate further in the study.

### 3.1 Results and Analysis of the Online Google Survey

In the survey, the manufacturers needed to select the type of system their IBT falls within. *Table 1* shows the response distribution of system types the 8 respondents provided.

As demonstrated in *Table 1*, IBT systems are diverse in their makeup. Most of the manufacturers selected to offer their own terminology to describe their system instead of selecting an option provided in the survey. System type options provided in the survey were modular block system, panelling system, modular block & framing system, and panel & framing system. What starts becoming clearer is that the current South African IBT systems are difficult to categorise. But some of the additionally added categories could be combined into the categories provided in the survey.

Each IBT manufacturer has their own terminology for describing their system and therefore so many additional categories were added but, there is room for consolidation. In *Table 2*, it is demonstrated that the IBT systems and products can be categorised according to the generalised categories provided in the survey, the survey question did not aim to gain detailed descriptions of the systems or products. As shown in the *Table 1 and 2,* most systems in the sample space are panel and framing systems (5 out of 8) with the rest (3 out of 8) being modular block systems.

The two main requirements to determine a system's applicability for self-build projects, is to identify whether the IBT system or product can be completely disassembled into its original components after it has been assembled and the degree of complexity involved in the assembly process. Participants were asked if their systems lend themselves towards design for disassembly. As shown in *Figure 3*, 75% (6 out of the 8 respondents) of the participants indicated that their systems cannot be disassembled. This can be attributed to the level of permanence involved in the joinery of the systems. The process of fixing the IBT components to each other range between engineered mortar and adhesives, specialised nails and brackets, galvanised channels fixed to reinforced concrete raft foundations, lightweight steel framing structures and internal reinforces steel cages. The whole or

| Study Participant Number | Modular Block | Panel | Modular Block + Framing Stucture | Panel + Framing Structure | Other | Own Answer |
|---|---|---|---|---|---|---|
| 1 | | | | | X | Interlocking dry-stacking building technology |
| 2 | | | | | X | Structural and/ or infill panel system |
| 3 | | | | | X | Reinforced concrete walling |
| 4 | X | | | | | |
| 5 | | | | | X | SIP panel system |
| 6 | | | | | X | Modular precast panel system, fast delivery, scalable, green |
| 7 | | | | X | | |
| 8 | X | | | | | |

*Table 1: Showing the answers provided by the study's participants & how they classify their system type (Author, 2023).*

complete structure needs to be able to be disassembled back to its components to be considered as system designed for disassembly. Ease of assembly accounts for another key characteristic of self-build friendly systems. When participants were asked about the level of complexity associated with assembling their system, most indicated that their systems were uncomplicated to install, and only semi-skilled labour is required.

The South African Institute for Architects (SAIA) defines an architectural project according to the following phases: (1) Project inception, (2) Concept development and project feasibility, (3) Design development, (4) Procurement and Documentation (preparation for tender and council submissions), (5) Construction, (6) Practical completion and project handover, and lastly (7) Project close out (SAIA,

| Study Participant Number | Modular Block | Panel | Modular Block + Framing Stucture | Panel + Framing Structure | Other | Own Answer |
|---|---|---|---|---|---|---|
| 1 | X | | | | | Interlocking dry-stacking building technology |
| 2 | | | | X | | Structural and/ or infill panel system |
| 3 | | | | X | | Reinforced concrete walling |
| 4 | X | | | | | |
| 5 | | | | X | | SIP panel system |
| 6 | | | | X | | Modular precast panel system, fast delivery, scalable, green |
| 7 | | | | X | | |
| 8 | X | | | | | |

*Table 2: Showing that the systems can be classified according to the system type options provided by the survey (Author, 2023).*

n.d.). During the construction processes required in the fifth phase of an architectural project there is an opportunity for skill sharing between the professional team and the labour team. In *Figure 4*, the results from the survey show that most of the participants consider their systems to be uncomplicated to assemble. Only 25% of respondents indicated that a semi-specialised level of assistance is required to assemble the system when on site. This is a promising indication. It suggests that a shift in accessibility has occurred, systems are designed specially to be uncomplicated so that more labourers can partake in the IBT construction industry without extensive and formalised training beforehand. By lowering systems' installation complexity more people, including a layman, can understand these systems and put them into use. South African IBT systems have started to account for the country's low level of education and how this impacts job creation within the construction

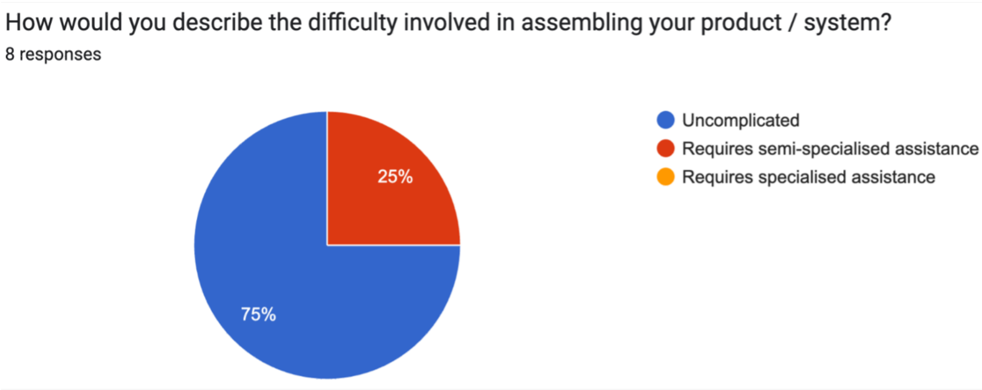


*Figure 3: indicates the ease of assembly for the IBTs in the study by investigating the system's level of complexity (Extracted from the Google survey's results, 2023).*

industry. ASA certified products require detailed monitoring during and post construction (phase 5 of a project) because the systems must be assembled according to the certified ASA document for it to meet building regulations and qualify for project sign off during phase 7 of the project. This means that there is a degree of training still needed to install these systems.

Most of the participants indicated that they provide training to interested contractors wishing to become accredited to install their systems. The training often happens *in-situ* due to the systems' complexity levels being kept low. Participant 8 indicated they have a couple of contractors they prefer to work with, and therefore, readily recommend these contractors to clients. These contractors know their system, practices, and technical requirements very well and install the system precisely as indicated in the technical drawings. The other respondents stated that they provide moderate training in their factories to contractors enabling as many people as possible to work with their systems. Small scale training operations occurring as needed means that the systems leave contractors with an earning potential after completion of the first building phases, making IBT systems more accessible to contractors. This can be proven useful for a self-build typology.

*Figure 3* showed the possibility for complete disassembly of the 8 IBT systems in the study. Since the majority answered that their systems could not, the next question was asked to understand the

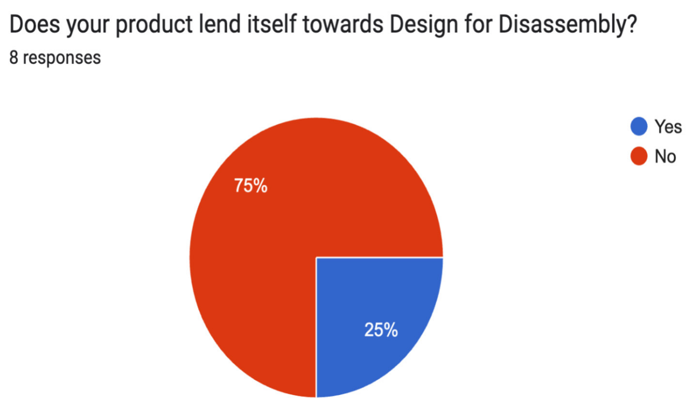


*Figure 4: indicates the percentage of the participant IBT systems that can be disassembled (Extracted from the Google survey's results, 2023).*

system's product life cycle was asked: Can your product be reused once it has been disassembled? At first it seemed as though the respondents misunderstood the question because 2 respondents said 'no' to the Design for Disassembly question but 'yes' to the material reuse question, as shown in *Figure 5*. Sustainable human development practices, in this study, not only considers design flexibility and system disassembly as requirements for self-build projects but it also reflects on the life cycle of the system or product. If the system cannot be reverted into its components without damaging the system's structural integrity and reused in a different configuration, could the components be broken down and recycled and reintegrated into the process of manufacturing new composite components? For most of the respondents the answer was yes (66.7% of responses). In *Figure 5*, respondents indicated that their systems could be reused and reassembled in another form once it has been disassembled. This suggests instead that the system or products are reusable but cannot be completely disassembled back into its original components. The product life cycle is improved

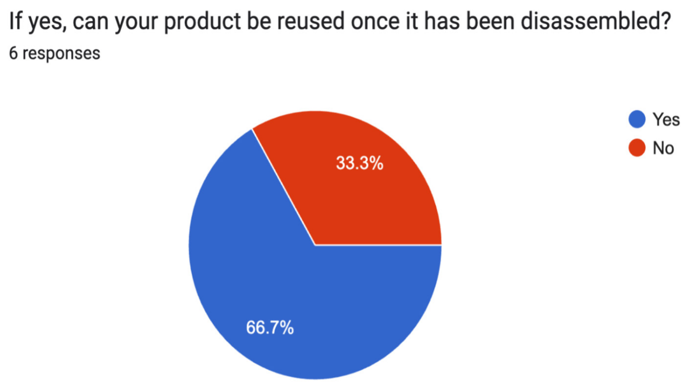


*Figure 5: indicates the percentage of the participant IBT systems that can be reused after disassembly (Extracted from the Google survey's results, 2023).*

though, which is already a partial step towards decreasing building obsolescence but not a full step yet towards versatility in a self-build typology and this study's objective.

The study aims to answer a typological suitability question as well. The survey asked participants to suggest the typologies which they consider to be the most appropriate for their systems. *Table 3* shows the 8 participants, their system type, which building occupancy classes they have been ASA certified, the typologies they believe their system has had the most success in, and the number of projects that have been completed using their system in the last 5 years.

According to the certified occupancy classes indicated by the participants, the two common occupancies between all the participants were: A3 (Places of Instruction) and G1 (Offices) making using use of both modular block IBTs and panel and framing structure IBTs. When asked which typologies participants believe are best suited to their system or product, as shown in figure 6, student housing (25%) and free-standing, low-cost housing (25%) received the most votes with the other typologies each receiving 12,5%. These typologies being clinics, internal renovation within existing buildings, free-standing, middle income housing, and classrooms. The sectors of student and free-standing, low-cost housing require a shortened construction timeframe due to the great need for housing they fulfil. Student housing aims to create fast lodgings *en masse* in tower typologies while low-cost, free-standing housing developments are phased to ensure clusters of houses are completed at once and allow faster resident occupation to occur.

Another consideration is the level of access the public has to IBT systems and products, as it is essential for a self-build culture to fully realise. This really means that there is a need to commercialise IBTs and make them available to the public market for purchasing. Manufacturers indicated that most of their companies already provide the required training for system installation but that their systems are also uncomplicated and only required semi-specialised assistance during assembly,

| **Study Participant Number** | **Sytem Type** | **ASA Certified Occupancy Class** (SANS 10400) | **Most Appropriate Typological** Application according to manufacturer | **No. of Projects completed in the last 5 years** |
|---|---|---|---|---|
| **1** | Modular Block | A1, A2, **A3**, A4, B3, C1, C2, D2, D3, D4, E1, E2, E3, E4, F1, F2, F3, **G1**, H1, H2, H3, H4, H5, J2, J3 | Housing (free-standing, affordable, low-cost) | Stated: numerous throughout SA |
| **2** | Panel + Framing Structure | **A3**, B2, B3, F2, E3, J2, J3, **G1** | Student Housing | ±50 |
| **3** | Panel + Framing Structure | **A3**, B2, B3, D2, D3, E1, E3, F1, F2, F3, **G1**, H2, H3, H4 | Student Housing | Stated: numerous throughout SA |
| **4** | Modular Block | **A3**, B2, B3, D2, D3, F1, F2, F3, **G1**, H2, H3, H4 | Housing (free-standing, middle income) | ±3 |
| **5** | Panel + Framing Structure | **A3**, A5, F2, **G1**, H2, H4 | Classrooms | 15 |
| **6** | Panel + Framing Structure | **A3**, **G1**, H2, H3, H4 | Housing (free-standing, affordable, low-cost) | 4 |
| **7** | Panel + Framing Structure | **A3**, F2, **G1**, H3, H4 | Clinics | 5 |
| **8** | Modular Block | A1, A2, **A3**, A4, A5, B1, B2, B3, C1, C2, D1, D2, D3, D4, E1, E2, E3, E4, F1, F2, F3, **G1**, H1, H2, H3, H4, H5, J1, J2, J3, J4 | Internal Renovations in Existing Buildings | ±40 |

*Table 3: Categorises the data collected according to the system stype, the certified occupancy classes, the number of projects completed in the past 5 years, and shows the typological applications participant’s feel best suit their IBT system (Author, 2023).*

see *Figure 4*. Commercialising IBTs requires that the number of risk variables need to be reduced so that the public can construction using these systems in their own capacity and potentially under the supervision of a specialised person. Unfortunately, the regulatory context of South Africa does not yet allow for such a condition to exist.

Participants communicated that throughout the ASA accreditation process they experienced many conflicts, redundancies, and limitations. The most significant difficulty experienced during the ASA application and certification process was the overall cost involved in product testing, the actual certification fee, and the cost involved in hiring industry specialists to certify their IBTs. Participants also voiced that the accreditation process is laborious and very slow and that this impacts their companies' project completion rates negatively as they cannot proceed on projects without a valid ASA certificate. The delayed response from ASA, according to the participants, is due to a limited understanding by officials of the specific system's technical data and requirements. The officials' restricted IBT knowledge base often results in product limitations or restrictive certifications. The result is that correspondence from ASA is slow, invoicing is behind, and the process of certificate amendments is overdue.

Public perception is another factor IBT manufacturers need to face. Currently, in South Africa, the perception surrounding IBT products and systems is negative. This could be attributed to the public being underinformed on the performance benefits of IBTs. For example, participant 8 states that there is an apparent fear amongst users to shift to modular, more performance positive IBT products. While participant 5 speculates that the initial cost implications of the IBT systems, when compared to the CBTs used in low-cost housing developments, often scare off potential users. Participant 3 attributes slow industry uptake to the disinterest shown by contractors to learn new construction techniques and procedures, although training is readily provided by IBT companies. Participant 8 states that they have seen hesitation from contractors because of fear that they will lose time during construction and as a result suffer a financial loss at the project's completion. Limitations are also experienced during the council approval phase of the project (phase 4). Participants 6 and 7 describe that resistance is experienced when submitting plans for council approval. Participants experience a low level of IBT system awareness and understanding by council officials. This becomes a compounded issue when banks are unconvinced or even unaware of the ASA accreditation system involved when building with IBTs and delay mortgage loans for housing projects as a result.

## 3.2. Results and Analysis of the Virtual Interviews

The 8 survey participants were contacted for specific information relating to their IBT systems in relation to the IBT industry in South Africa. Semi-structured interviews were used to ask additional and more detailed questions relating to their experience with ASA, energy efficiency and environmental sustainability of the system, the system's assembly process, how permanent the system is, how is it manufactured, what the site requirements are and, if specialised equipment is required to install the IBT systems on site.

The interviews were used to identify, amongst other things, whether the IBT system could be used in conjunction with CBTs. All the participants confirmed this and explained that construction projects, whether they are new builds or additions to existing buildings, will have certain elements constructed from CBTs, for example, the building's framing structure could be reinforced concrete or steel structures. The IBTs are then used for infill purposes if CBTs provide the structure. Participants 1,4, 5, and 6 all stated that their systems can seamlessly be integrated into a building that is also made up of CBTs. During the interviews, 75% of the participants stated that their systems require

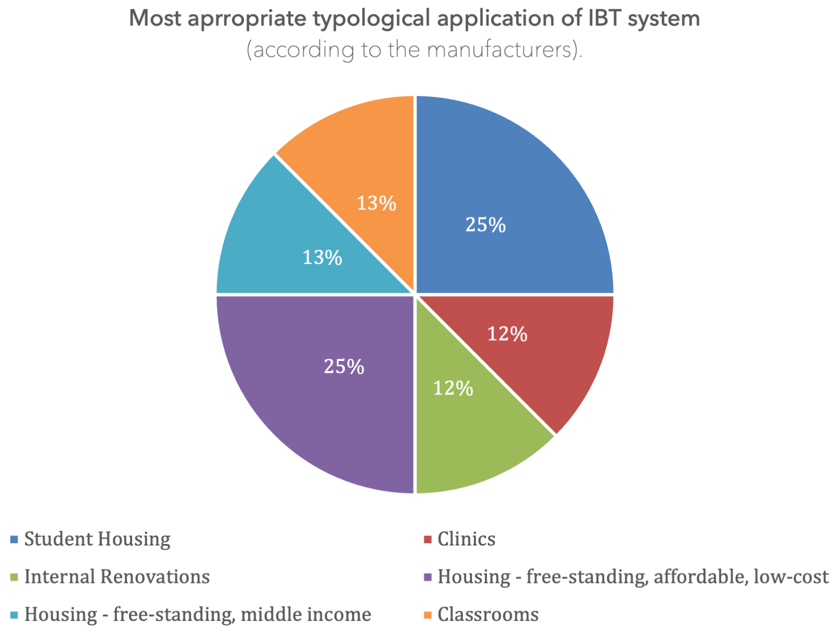


*Figure 6: indicates the typological preferences of the participants (Extracted from the Google survey's results, 2023).*

no additional or specialised equipment for installation, but that assembly instead relies on manual labour, or the equipment typically found on a construction site building with CBTs. This makes the overall building process simpler and uncomplicated when building with both CBTs and IBTs. All 8 participants stated that they often experience AEC professionals involved in projects to think that CBTs can simply be substituted for IBTs. For example, a CBT clay brick to be exchanged for and IBT modular block. The issue with this thought process is that IBT systems have different characteristics governing how they should be used than the rules involved in building with CBTs. A clear distinction made by all the participants was that the decision to build using IBTs needs to be made in the inception phase (phase 1) of the project. The design needs to be done according to the chosen IBT's structural parameters such as, maximum spans, the module size, optimal heights between the framing structure, all to ensure that the IBT system's structural integrity is maintained and that it will be constructed according to the technical specifications detailed in the ASA certificate.

To assess the degree of public accessibility of the participating IBT systems, the interviewees were asked how their system are made available to the public market. The responses indicated that most of the manufacturers distribute their systems themselves as the fabricators and wholesalers of the systems. This means that the systems can be purchased in quantities dictated by individual project requirements. Unfortunately, due to the need to maintain constant quality control measures as required by the ASA certificate, the public cannot purchase the systems without a professional who will construct the system. The inaccessibility of the IBT systems to the public market is limiting the ability of a layman or semi-skilled person engaging in a self-build project.

The study's aim is to identify if there is an IBT system, on the market in South Africa, that best lends itself towards a self-build application. When the participants were asked if their systems could be used in self-build projects, only the modular block manufacturers answered 'yes' to the question. The panel and framing structure system manufacturers stated that their panels are pre-planned and prefabricated under factory conditions and that the assembler on site has no autonomy in how the panels are to be assembled *in-situ*.

It is for this reason that the study will consider the modular IBT blocks further in in determining if there is an IBT on the South African market best suited to a self-build typology. The proposed systems for further study are:

1. Hydraform Building System
2. Green Crete Smart Block

## 3.3. IBT system comparison: Hydraform Building System and Green Crete Smart Block

### 3.3.1. Hydraform Building system: Interlocking dry-stacking modular blocks.

The Hydraform Building System consists of earth-cement blocks which are manufactured by the mobile Hydraform block-making machine on-site and uses local or site soil as a main part of the mixture (the mixture consists of soil, water, cement, and lime where necessary). These machines can be transported between sites and are sold to interested parties in the construction industry. The modular blocks are standardised through the machine-making process, and this limits the margin of error typical of a construction project. The blocks are moulded specially to allow a dry-stacking assembly, as shown in *Figure 7*, process allowed for by the interlocking grooves that keep the blocks in place. The result is a solid block, that passes the “knocking” test eliminating the hollow sound typically found in drywalling or panel IBT systems. The construction process of a building encompasses both innovative and conventional technologies, for example, the system requires a conventional foundation, floor surface, waterproofing procedures, and roof construction in tandem

*Figure 7, Hydraform. (n.d.) Interlocking soil-brick. Available from: https://www.hydraform.com/products/brick-paver-and-blockmaking-machines/ [Accessed: 2023-7-15].*

with the IBT block system. The blocks, once moulded, are stacked on site, and covered with plastic sheeting for 24 hours to allow curing. Construction can commence 72 hours after the block moulding process. The 110mm wide blocks are manufactured in one grade, with nominal compressive 28-day strength of 4MPa. As far as finishes go, the blocks could be left as is but are often skim plastered and painted for a more aesthetic finish. The 110mm wide block system is self-supporting between 1800mm and 2200mm, beyond this height, conventional framing structures are required by the ASA and NBR legislation.

The socio-economic benefits of the system include local community training and employment which ensure long term sustainability of jobs and local development instead of external contractors, community members take ownership and pride in their developments, project earnings are retained within the community, and local materials alongside localized production enables maximum community involvement and participation leading to economic empowerment.

### 3.3.2. Green Crete: Smart Lightweight Block

The Green Crete block is manufactured from a mixture consisting of cement and waste ash or waste slag and polystyrene waste. The company's environmental sustainability policy is to only use waste materials and not to manufacture the ingredients required for their aggregate mixtures, for example, no virgin polystyrene chips are used. The benefits accrued through this process is that material cost is reduced, reciprocal relationships are fostered within the industry as they offer an alternative way for companies to dispose of their manufacturing waste, manufacturing is faster because the

*Figure 8, Green Crete (n.d.) Lightweight Blocks made with waste polystrene products. Available from: https://greencrete.co.za/our-product/ [Accessed: 2023-07-15].*

curing process of the blocks are shortened, the environmental impact of the blocks are much lighter than CBT clay bricks, and no toxic fumes are emitted during the manufacturing process or when cut during the construction process. The company has factories located throughout South Africa in Gauteng, the Western Cape, and the Eastern Cape. This allows their transportation lengths to sites to be reduced and as a result have a lower CO2 emission level.

A lightweight building block, shown in *Figure 8*, of 700 x 340 x 120 mm manufactured with waste polystyrene, cement, fly-ash, perlite, and fibres are used to create a smart block. The result is a solid block, that passes the “knocking” test eliminating the hollow sound typically found in drywalling or panel IBT systems. The maximum unsupported height of the system is 5 meters, and the system is not load bearing in terms of slabs but it can carry any roof structure. Finishing of the system is done using Lightweight Insulated Plaster (LIP) which has better performance characteristics than conventional sand plaster.

The socio-economic benefits of the system include increasing employment of unskilled labour, increases affordability within the low-cost construction industry, and assists in addressing the housing backlog in the country through shortened construction timeframes.

| | **Criteria: Assessing the IBT's appropriateness for self-build** | **Hydraform Building System** interlocking dry-stacking modular blocks. | **Green Crete** Smart lightweight block |
|---|---|---|---|
| **1.** | **Economic Sustainability** (the IBT system needs to be comparable to CBT brick and mortar construction) | • manufactured *in-situ*.<br>• uses soil on site.<br>• reduced labour costs, self-build construction option<br>• minimal need for external materials, can help lower overall construction expenses further | • decreased material cost: majority of materials used are waste or recycled materials.<br>• Factories are distributed, transportation costs are lower.<br>• Increases speed of construction |
| **2.** | **Feasibility** (cost over short- and long-term projects: when used in small business interventions, household alterations / new builds and social infrastructure) | The initial input cost is purchasing the block-making machine, thereafter costs are limited to purchasing cement and soil testing | The blocks are lightweight this means that the supporting structures need to carry less weight and need for maintenance is not increased beyond what is required for a CBT brick building. |
| **3.** | **Opportunity of system disassembly** (without product or system damage) | The dry-stacked bricks can be taken apart (if plastered, this can be lightly chipped off) and reassembled else-where or in a new configuration. | The system cannot be disassembled. Assembling the systems includes a galvanised u-channel to be fixed to the conventional foundation, the blocks are then glued into place using a tile-cement mixture, once the wall is erected, a glass fibre mesh is wrapped on the internal and external faces of the walls, and then finished with LIP. |
| **4.** | **Opportunity for reuse** (disassembled original components or crushed and reintegrated into new components) | The soil bricks can be crushed and reintegrated into new blocks as aggregate. | The blocks can be crushed and reintegrated into new blocks as aggregate. |
| **5.** | **Lightweight system** for ease of transportation and carrying around on-site | The system is not lightweight once assembled, but individual blocks can easily be carried by people. | Blocks are lightweight and the module size of 700 x 340 x 120 mm is easy to carry. |
| **6.** | **Ease of assembly** (system needs to be uncomplicated system to enable semi-skilled labourers to participate in self-building) | The interlocking nature of the blocks eliminates the need for skilled masons or specialised construction expertise. | Blocks can be cut using a timber saw *in-situ* which limits the need for large equipment on site. Unskilled or semiskilled labour is sufficient for construction. |

| | Criteria: Assessing the IBT's appropriateness for self-build | **Hydraform Building System** interlocking dry-stacking modular blocks. | **Green Crete** Smart lightweight block |
|---|---|---|---|
| 7. | **Sustainable construction** (sustainable building practices: limited material wastage and efficient use of CBT materials for supporting structure) | The system utilises locally available soil resources, reduces the need for transportation of building materials, and minimises waste generation. | Manufactured with waste polystyrene, cement, fly-ash, perlite, and fibres as the aggregate and then mixed in with cement. |
| 8. | **Made in South Africa** | Yes, moulded *in-situ*. | Yes, moulded in widely distributed factories across the country. |
| 9. | **Open design system** (system or product can be assem-bled in a variety of ways) | Structures can be customised in their configuration based on their specific needs, preferences, and available resources. The interlocking blocks can be easily modified or ad-justed during construction to ac-commodate changes in design or layout. | Structures can be customised in their configuration based on their specific needs, preferences, and design. Blocks can also be easily cut to size to accommodate design flexibility. |
| 10. | **Empowerment and self-sufficiency** (in the context of self-build projects) | One block-making machine can manufacture the blocks for innumerable projects. Training to use the machine is achieved within a week and *in-situ.* This means that communities can use a singular machine to redevelop their neighbourhood. Once buildings become obsolete, its blocks can be disassembled, the blocks can either be used to build something else or be crushed and used in the making of new blocks. | The supply of waste or recycled materials will not end. This means that the manufacturing process will con-tinue indefinitely, and the system will continue to play a positive role within the construction industry. The blocks are easy to build with and can be cut without machinery on site. Once buildings become obsolete, its blocks can be disassembled and crushed and used in the making of new blocks. |

*Table 4: Categorises the data collected according to the system stype, the certified occupancy classes, the number of projects completed in the past 5 years, and shows the typological applications participant's feel best suit their IBT system (Author, 2023).*

## 4. Discussion

South Africa faces many housing and infrastructural challenges, particularly within low-cost, government-facilitated, and informal construction sectors. Integrating IBTs with self-build practices could democratize the housing construction industry and empower communities in the country. However, the prevailing preference for CBTs, such as clay brick masonry, over IBTs is hindering progress and is further aggravated by the limited number of precedent projects available and narrowed focus on further developing IBTs. The study's participants stated that there is a need for greater awareness and understanding of IBTs' benefits by professionals and policymakers. Furthermore, the limited application of IBTs in the private sector is attributed to the complexities of industry relationships, the procurement process, lack of technical information, and scarcity of experienced labour.

The study's low participation levels serve as a further reflection of the current state within the IBT industry. These reduced levels of engagement may be attributed to the outdated ASA contact lists or possibly indicate a lack of interest among IBT professionals in participating in research aimed at raising awareness about the industry. Moreover, ASA appears to face challenges in fulfilling its responsibility to provide sufficient assistance and accessible information about IBTs to the public. The delays in issuing certificates, updating existing ones, and ensuring a comprehensive and easily accessible knowledge base may contribute to the limited adoption of IBT systems.

It appears that the government of South Africa has indeed recognized the importance of integrating IBTs with local communities to facilitate economic development and increase project success. The NHBRC survey also indicates that the government considers criteria such as speed, value for money, and structural reliability when evaluating IBTs. Additionally, the government's measures to promote awareness and use of IBTs, such as establishing innovation hubs, implementing sustainable strategies, and considering local community needs, reflect their commitment to advancing the construction industry in a more sustainable and inclusive direction. However, it is essential to acknowledge that the situation on the ground may not align with such optimistic assessments. The study's participants express dissatisfaction and concern regarding the bureaucratic processes involved in obtaining ASA accreditation for their systems, which creates frustration when trying to participate in tenders for social housing developments, financing from banks, and access to professional insurance. Highlighting the gap Agrément isn't filling, the argument emphasizes the necessity for a shared and evolving knowledge base, open communication channels, and clear feedback mechanisms to make informed decisions. Facilitating this process may involve leveraging information and communication technologies and linking leadership forms that encourage the free flow of ideas, people, and resources (Nederhand, J., Bekkers, V., & Voorberg, W.  2015).

The self-build typology has been investigated in the global North within the housing typology to a great extent, but there is very little evidence of the typology being studied in the Global South and more specifically in South Africa. Self-build practices allow urban dwellers to construct and maintain their own buildings, empowering communities and promoting dignified living. Informal settlements, though challenging the urban order, offer lessons in economic and social benefits that could be applied in self-build projects. The inclusion of IBTs could offer faster solutions for self-build projects by simplifying construction processes and utilizing modular and recyclable materials.

The survey results showed that IBT systems in South Africa are diverse and challenging to categorize. Panel and framing systems were the most common, followed by modular block systems. The Hydraform Building System and the Green Crete Smart Block were studied further. Both systems allow for recycling, their blocks can be ground down and added to the aggregate mixtures used in moulding new blocks. When comparing the two systems, both have economic and environmental sustainability advantages, but the Hydraform system allows for disassembly and reuse, making it more suitable for self-build projects. The Green Crete system is easier to manufacture and transport but lacks the ability to be disassembled. Local context and resources play a significant role in selecting appropriate IBTs for self-build interventions.

Overall, the study aims to identify an IBT system in South Africa best suited for self-build projects, and the results suggest the Hydraform Building System may be a better fit due to its ability to be disassembled and reused, empowering communities, and promoting self-sufficiency in construction projects. While Hydraform presents advantages for self-build projects, it still falls short of meeting all sustainable construction requirements. One concern is the potential over-extraction of soil from the construction site, depleting the property's resources for block production. Additionally, the petrol or diesel-powered mould-making machine raises environmental concerns amid the ongoing climate crisis. Further improvements are needed to enhance its sustainability credentials.

The observed trend in end-users' perceptions regarding IBTs used in home construction leans towards favouring solid blocks over other types like prefab or composite panels. This preference arises from concerns about the sound produced during the "knock test," where panelling systems can sound hollow. As a result, it is suggested that panelling systems are more suitable for short-stay typologies such as schools, clinics, offices, and small commercial buildings. When it comes to IBT-constructed houses that individuals intend to own, the expectation is for them to be "solid" and of equal or potentially better quality than conventional brick and mortar houses. Panel and frame systems implemented in housing developments have faced rejection due to perceived inferior quality and a lack of aesthetic value compared to what is perceived as a 'real house.'

## 5. Conclusion

This study highlights the country's suffering due to a shortage of appropriate infrastructure and adequately skilled labour for construction projects. The housing backlog leads many eligible citizens to live in informal settlements while waiting for subsidized housing. Access to information is generally limited regarding IBTs. The ASA website and database serve as the primary source of information for potential clients and AEC industry professionals. However, the information provided in the ASA database is not comprehensive enough to offer a clear understanding of the IBT system's appearance, functionality, and the conditions necessary for its optimal performance. To address these issues, promoting self-build projects becomes essential, necessitating the revision of planning frameworks with the integration of GCs for building adaptability and community engagement. However, the regulatory context, conflicting policies, and lack of understanding, by officials and laymen alike, impede their implementation in the industry. The regulatory context within South Africa, including the DHS, ASA, and the NHBRC, play a significant role in shaping policies and influencing the AEC industry's willingness to adopt IBTs. The regulatory frameworks in South Africa do not adequately support the development of new materials and systems, especially in the IBT industry. Unfortunately, these frameworks do not adequately support the development of new materials and systems in the IBT industry, leading to a laborious and frustrating certification process for new IBTs. Therefore, designing for disassembly becomes crucial for sustainable practices and challenging the industry norms of permanence, offering self-build typologies the advantage of low-tech connection points and flexible systems for easy disassembly and reassembly.

A sociological lens emphasizes the interdependence of IBT type and typology. Currently, the most suitable IBT for a self-build typology in South Africa is a modular block that can be either pre-manufactured in a factory or made *in-situ*, promoting accessibility and potential alternatives to formalizing informal settlements within South Africa.

## 6. Recommendations

Recommendations for promoting and facilitating the use of IBTs in the construction industry:

- **Policy Amendments:** amend building regulations to allow for self-build projects, making it easier for individuals and communities to participate in constructing their homes. Example amendments could be:

  - *Streamlined Permitting Process:* Simplify the permitting process for self-build projects, reducing bureaucratic hurdles and paperwork. Implement an expedited review process specifically tailored to self-build initiatives. For example, introducing self-build kits for IBTs resembling the convenience of flat-packed furniture assembly kits. These kits can be overseen by AEC industry professionals, and local councils may grant pre-approved licenses to end-users for acquiring the IBT kits. By offering pre-mixed and pre-measured materials, this approach mitigates construction risks and facilitates user participation.

  - *Flexible Building Codes:* Develop building codes that provide more flexibility for self-build projects, allowing for innovative construction methods and materials while still ensuring safety and structural integrity.

  - *Accessible Information:* Provide easily accessible and comprehensive information about building regulations, processes, and requirements specifically tailored for self-builders.

  - *Training and Support:* Offer training and support programs for self-builders to enhance their understanding of building regulations, construction techniques, and best practices.

  - *Community-Based Approvals:* Explore the possibility of community-based approvals for self-build projects, involving local residents in the decision-making process (ties into the concept of self-governance)

  - *Permit Fee Reductions:* Consider reducing permit fees for self-builders to make the process more affordable and attractive.

  - *Recognition of Alternative Technologies:* Acknowledge and incorporate alternative building technologies, including IBTs, into building regulations, promoting their use in self-build projects.

  - *Collaboration with Self-Build Organizations:* Collaborate with self-build organizations and experts to gather valuable insights and feedback to improve regulations and address potential challenges.

    These amendments aim to create a more supportive and conducive regulatory environment for self-builders, empowering individuals, and communities to actively participate in the construction of their homes.

- **Establish a Governing Body:** Create a governing body to assess the complexity of IBT system installation and construction. This body should also focus on identifying opportunities for skills transfer during project execution, particularly in phase 7 of a construction project.

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# 8. Appendices

## 8.1. Ethical Clearance & Participant Permission Documentation

UNIVERSITEIT VAN PRETORIA
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Faculty of Engineering, Built Environment and Information Technology
Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie / Lefapha la Boetšenere, Tikologo ya Kago le Theknolotši ya Tshedimošo

21 April 2023

Reference number: EBIT/57/2023

Miss CJ Shaw
Department: Architecture
University of Pretoria
Pretoria
0083

Dear Miss CJ Shaw,

**FACULTY COMMITTEE FOR RESEARCH ETHICS AND INTEGRITY**

Your recent application to the EBIT Research Ethics Committee refers.

Conditional approval is granted.

This means that the research project entitled "The role of Alternative Building Technologies in Sustainable Human Settlements" is approved under the strict conditions indicated below. If these conditions are not met, approval is withdrawn automatically.

Conditions for approval:

If the respondent doesn't own the company, permission letter(s) are required.

Company's name and details are to be separated from the original data set and replaced with a code. Later these contact details need to be erased completely after the project has completed.

Reove "Upon signature of this form, the participant will be provided with a copy" as this is an online questionnaire there is no place to sign.

This approval does not imply that the researcher, student or lecturer is relieved of any accountability in terms of the Code of Ethics for Scholarly Activities of the University of Pretoria, or the Policy and Procedures for Responsible Research of the University of Pretoria. These documents are available on the website of the EBIT Ethics Committee.

If action is taken beyond the approved application, approval is withdrawn automatically.

According to the regulations, any relevant problem arising from the study or research methodology as well as any amendments or changes, must be brought to the attention of the EBIT Research Ethics Office.

The Committee must be notified on completion of the project.

The Committee wishes you every success with the research project.

Kai-Ying

Document required for signiture by each of the participants before they commenced with the completion of the Google Survey

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University of Pretoria
Masters (Professional) Architecture

Research Project: The role of Alternative Building Technologies in Sustainable Human Settlements

Permission to Participate in Survey

I (Company Owner) ________________________________________, the undersigned, hereby consent to (Employee/Appointed Representative) ____________ ________________________ to participate and complete the Google Form titled: “IBT - Manufacturers”, on behalf of me, the owner of (Company Name) ______________________________________.

Owner’s full name & signature:

Date:

Employee/Appointed Representative’s full name & signature:

Date:

## 8.2. Google survey questions



# IBT - Manufacturers

**Dear Sir/Madam,**

**We (Cecilia Snyman and Courtney Shaw) are Master's students from the School of Architecture at the University of Pretoria, under the supervision on Dr Coralie van Reenen of the CSIR.**

**Our research is titled: "The role of Alternative Building Technologies in Sustainable Human Settlements"**

**Our study aims to identify and better understand the position of Innovative Building Technologies (IBTs) within the Built Environment of South Africa and ultimately contribute to promoting the uptake of IBTs as alternative building solutions to conventional masonry construction.**

**The purpose of this questionnaire is to gather information about the selected IBT system and it's relationship to the larger discourse in terms of sustainable future development across South Africa.**

**You were chosen as a respondent because of your company's active contributions to the development of a specific IBT system.**

**Your participation is voluntary and you can withdraw at any time without penalty. Throughout the survey your privacy will be protected and your participation will remain confidential. We do not wish to analyse data individually and all the data will be transferred to a computer programme to analyse the entire sample group. This means that you are assured of anonymity.**

**If you agree to participate, please complete the survey that follows this cover letter. It should take about 15 minutes of your time at the most. By completing the survey, you indicate that you voluntarily participate in this research. If you have any concerns, please contact our Research Supervisor with the detail provided below.**

**Researcher name: Dr Coralie van Reenen**

**Email: cvreenen@csir.co.za**
**We would like to thank you in advance for taking the time to answer our questions and assisting us in gathering the information necessary to complete this research investigation.**

* Indicates required question

1. 2.1 I, the undersigned, hereby voluntarily grant my permission for participation in the project as explained to me by Dr C van Reenen and assistants. *

   2.2 The nature, objective, possible safety and health implications have been explained to me and I understand them.

   2.3 I understand my right to choose whether to participate in the project and that the information furnished will be handled confidentially. I am aware that the results of the investigation may be used for the purposes of publication.

   2.4 Upon signature of this form, the participant will be provided with a copy.

   I will remain anonymous my comments may be used without giving any geographic or personal references (name, address, ID, occupation, age, income etc) that may accidentally imply my identity.

   *Mark only one oval.*

   - Yes
   - No

Company Details

Information gathered will be used strictly for research purposes only. All data will be saved in an access controlled digital location and will not be shared with a third party.

2. Please state your Company name? *

   ______________________

3. Are you the Owner of the Company? If you are not the Owner, please complete the attached Permission Form in the email. *

   *Mark only one oval.*

   - Yes
   - No

4. Contact Person's full name *

5. Contact's Email Address *

6. Where is your factory / manufacturer located? *

7. May we contact you for a more detailed interview?

*Mark only one oval.*

- No
- Yes

IBT SPECIFIC QUESTIONS

The following questions are directed towards your IBT product / system.

8. A short description of your IBT product/system *

9. What occupancy class (according to SANS 10400) is your product / system certified for? *
(Select all that apply)

*Tick all that apply.*

- [ ] A1 - Entertainment and public assembly
- [ ] A2 - Theatrical and indoor sport
- [ ] A3 - Places of instruction
- [ ] A4 - Worship
- [ ] A5 - Outdoor sport
- [ ] B1 - High risk commercial service
- [ ] B2 - Moderate risk commercial service
- [ ] B3 - Low risk commercial service
- [ ] C1 - Exhibition hall
- [ ] C2 - Museum
- [ ] D1 - High risk industrial
- [ ] D2 - Moderate risk industrial
- [ ] D3 - Low risk industrial
- [ ] D4 - Plant room
- [ ] E1 - Place of detention
- [ ] E2 - Hospital
- [ ] E3 - Other institutional (residential)
- [ ] E4 - Health care
- [ ] F1 - Large shop
- [ ] F2 - Small shop
- [ ] F3 - Wholesalers' store
- [ ] G1 - Offices
- [ ] H1 - Hotel
- [ ] H2 - Dormitory
- [ ] H3 - Domestic residence
- [ ] H4 - Dwelling house
- [ ] H5 - Hospitality
- [ ] J1 - High risk storage
- [ ] J2 - Moderate risk storage
- [ ] J3 - Low risk storage
- [ ] J4 - Parking garage
- [ ] Other: ____________________

10. How many storeys is your system certified for? *
(Select all that apply)

*Tick all that apply.*

- [ ] One storey
- [ ] Two storeys
- [ ] Three storeys
- [ ] Four storeys
- [ ] Other: ______________________

11. What were some of the limitations experienced during the Agrement Certification process? *

*Tick all that apply.*

- [ ] Cost of certification
- [ ] Cost of product testing
- [ ] Product limitations
- [ ] Other: ______________________

12. Which category best describes your product best? *

*Mark only one oval.*

- ( ) Modular Block System
- ( ) Infill Panelling System
- ( ) Modular block + Framing System
- ( ) Panel + Framing System
- ( ) Other: ______________________

13. How many projects have used your system in the last 5 years? *

______________________

14. What type of project / building has proven to be the most suitable for application of your IBT system?

*Mark only one oval.*

- Housing (free-standing affordable / low-cost)
- Housing (free-standing middle income)
- Multi-unit residential
- Classrooms
- Clinic
- Student housing
- Internal renovations in existing building

15. Where, in South Africa, are the majority of your projects located? *

________________________________

16. What strategies do you use to promote your product? *

*Mark only one oval.*

- Social Media
- Professional Contacts & Representatives
- Educational Interactions
- Other: ________________________________

17. Does your product lend itself towards *Design for Disassembly?* *

*Mark only one oval.*

- Yes
- No

18. If yes, can your product be reused once it has been disassembled?

*Mark only one oval.*

- Yes
- No

19. How would you describe the difficulty involved in assembling your product / system? *

*Mark only one oval.*

- Uncomplicated
- Requires semi-specialised assistance
- Requires specialised assistance
- Other: ____________________

20. How does a company or individual obtain a license to install your product? *

_______________________________________________
_______________________________________________
_______________________________________________
_______________________________________________
_______________________________________________

21. As a manufacturer of an IBT, what are some of the challenges you have faced in comparison to those who use traditional building techniques? (e.g. costs, maintenance, flexibility of use in the system over time)

_______________________________________________
_______________________________________________
_______________________________________________
_______________________________________________
_______________________________________________

22. Is there anything else you would like to share or elaborate upon regarding your system?

## 8.3. IBT manufacturers interview questions

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Dear IBT Professional,

*Thank you for your continued willingness to participate in our study and provide us with your valuable experience and knowledge in the field of IBTs.*

This study aims to identify and better understand the position of Innovative Building Technologies (IBTs) within the Built Environment of South Africa and ultimately contribute to promoting the uptake of IBTs as alternative building solutions to conventional masonry construction.

Below are the questions for your consideration relating to IBT products and systems. We, MArch Students at the University of Pretoria - Cecilia Snyman and Courtney Shaw, would greatly appreciate your help in answering the following questions in as much detail as you can give. The information from these questions will prove to be extremely valuable in our continued research surrounding our study titled, *'The role of Alternative Building Technologies in Sustainable Human Settlements.'*

Upon the reply of these questions, we will like to schedule an in-person appointment with you to further discuss the information you have provided below.

All collected data (i.e. original dataset with perhaps identifiable information) and other related information (i.e. recordings, transcriptions) accumulated for this research study / research project will be stored in a secure storage space (i.e. electronic data or hard-copy data). Access to the original data will be limited to only team members. This enables researchers to ensure the anonymity and confidentiality of participants. De-identified datasets used for analysis will be stored on the University of Pretoria research data repository and platform (https://researchdata.up.ac.za/). The University of Pretoria manages, maintains, and controls this platform. All data stored on the mentioned platforms will be disposed of and destroyed after the prescribed period and by means of the prescribed method as defined by the University of Pretoria Information Management policy.

Questions:

1. What supplementary construction systems and materials are required in tandem with the IBT system? (i.e. existing concrete surface bed, steel or concrete frame structure, pile or strip foundations, roofing system)
   Your answer…

a. What tools are required on site?
   Your answer…

b. Are there specific conditions the site needs to be in to allow for effective installation?
   Your answer…

2. Could we get contact information to contractors, project managers and/or site managers to interview on implementation and the end product?
   Your answer…

3. Upon which climatic-response principles is the system based? (Thermal Mass, Ventilation, Insulation, Shading etc)
   Your answer…

4. Does your product have technical data sheets? (Insulation r/u values, material composition)
   Your answer…

5. Is there a standard construction detail that is applied to assembly/construction of the system on site? Access to construction detailing (Plans, sections, elevations)
   Your answer…

6. What is your understanding of environmental sustainability in the built environment?
   Your answer…

7. What are the various processes of manufacturing the IBT system requires (machinery, outputs, by-products etc)?
   Your answer…

8. What type of transportation methods are used to get the system to site? (as a measure of embodied energy)
   Your answer…

9. Are there any limitations of the system in comparison to its conventional building technology counterpart? (height, spans, durability)
   Your answer…

10. What are the maintenance requirements as well as life-expectancy of the system?
    Your answer…

11. How is your IBT system assembled?
    Your answer…
    a. Is it a prefab system installed in-situ?
       Your answer…
    b. A modular system constructed on site?
       Your answer…

12. Can your IBT system be bought in small quantities?
    Your answer…

13. Who may / has the opportunity to buy your IBT system?
    Your answer…
    a. Do they need to be certified?
       Your answer…
    b. Can the public acquire your system?
       Your answer…

14. Do you think your IBT system can be used in self-build architecture?
    Your answer…
    a. Is your system lightweight?
       Your answer…
    b. Can 2 people carry it readily?
       Your answer…

15. Does your system have a main framing structure that works separately to a secondary frame / infill system?
    Your answer…

16. Is your system designed within a closed or open design system, i.e. can it only be assembled in a single way?
    Your answer…