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ARE OPEN BUILDING PRINCIPLES RELEVANT IN THE SOUTH AFRICAN HOUSING SECTOR? CSIR INVESTIGATIONS AND ANALYSIS OF HOUSING CASE STUDIES FOR SUSTAINABLE BUILDING TRANSFORMATION

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Abstract
The CSIR Housing Research Group in collaboration with a number of partners has been investigating the concepts of sustainable building transformation in the South African housing sector. These studies have relied heavily on a number of theories, including Habraken's Supports, Open Building levels as well as concepts of material/component re-use. All of these theories provide approaches with regards to the way in which materials, building components and the buildings themselves are re-used or salvaged, based on life cycle analysis. There are numerous terms used to describe this approach to the design of the built environment and these are sometimes confusingly interchanged.

Thus, this paper presents descriptions of concepts and working definitions and then proceeds to carry this investigation further by analysing housing case studies with regards to sustainable building transformation. In this process it is attempted to assess if the approaches are relevant and applicable in the South African context. While it is acknowledged that these approaches to design and delivery need to be considered for the whole housing market, there is a pressing challenge to government to deliver low-cost and affordable housing. We also saw an assessment tool for existing buildings as an important way to try and influence thinking, design and planned delivery approaches at the conceptual stages, before future projects proceed in the typical manner which we perceive to be unsustainable.

The capacity for sustainable building transformation will be rationally assessed by studying the internal planning, construction methods and material selection of the selected projects. The paper presents a tool for assessment and comparison, studies the possible changes in the existing projects and also makes some basic recommendations for new projects.

Keywords: Open building, South Africa, housing, sustainable building transformation

BACKGROUND AND AIMS OF RESEARCH

The CSIR Housing Research Group in collaboration with a number of partners has been investigating the concepts of sustainable building transformation in the South African housing sector. Documents such as Medium Density Mixed Housing: sustainable design and construction of South African Social Housing (Osman and Herthogs, 2010); Environments of change: a design solution for an informal settlement in Mamelodi (Gottsmann and Osman, 2010); "Time" as a key factor in design and technical decision-making: concepts of accessibility, affordability, participation, choice, variety and change in the South African housing sector (Osman and Sebake, 2010) are products of these investigations.

As a continuation of this process, the CSIR is currently looking at issues of quality in housing and residential neighbourhoods through developing tools for assessment of housing projects. This comprehensive tool is not only intended to assess existing housing projects, but also to guide housing processes from the outset. The intended users are developers, designers, project managers and Social Housing Institutions. The tool encompasses a diverse set of criteria including technical aspects such as the integration of housing and servicing solutions and social aspects such as social cohesion through the design of shared open space proximate to housing developments.

This process emerged from a concern that, while South Africa is successful in delivering housing numbers, the quality of the environments being achieved is questionable. The two extreme poles in the housing sector are government-subsidised housing (so-called RDP houses which are give-away houses under the government's Reconstruction and Development Programme) and very upmarket developments. Both ends of this spectrum are based on the detached house on the middle of a plot in a sub-urban style planning layout.

It is the market between these two extremes that can perhaps offer opportunities for innovative housing solutions and multi-family typologies such as medium-density, mixed housing. Therefore, for the purpose of developing a tool for building adaptation, three case studies are selected that offer alternatives to the current, unsustainable housing models that dominate the South African urban landscape.

The theoretical background for this study is firmly rooted in an approach to architecture where the design of systems and the interface between systems is given importance. This is believed to generate a richer environment that caters for different categories of users, while at the same time achieves long-term relevance by allowing buildings to adapt and transform over time with minimum waste and minimum disruption to a higher-order level of the built environment that is more permanent and gives an urban setting its identity. This is also an attempt to achieve a balance between the shared domain of an urban environment and areas of individual control. In this sense, the environmental benefits that result from the increased potential for adaptability are further supported by the achievement of higher social benefits.

By assessing existing projects, it has been possible to argue that these theories are not only relevant and applicable in the South African context, but are of high priority if long-term sustainability of residential building stock is to be achieved. This assessment also allows for the identification and ranking of existing buildings that have high potential for adaptation (Teo et al, 2010) and therefore allows for strategic targeting of buildings for upgrades in urban regeneration projects, as an example. Teo (ibid) has also argued that this allows property managers to properly maintain buildings with least impact, as opposed to traditional upgrading mechanisms. The same author explains that building stock may become obsolete

due to physical, economic, functional, technological, social and legal criteria. Many existing buildings will have to be adapted in order to enhance their sustainability performance – adaptions such as rain water collection, modification of openings or installation of solar geysers. It can therefore be seen that the concept of "change" or "adaptability" is very broad and not restricted to one or other parameter, but rather encompasses a whole range of future possibilities that the designer will not be able to determine upfront.

SOME DEFINITIONS AND DESCRIPTION OF CONCEPTS

Two main factors determine the static nature of the existing built environment: irreversible connections (e.g. welding or cement joints) and the entanglement of constructional components with different lifespans (e.g. putting services in bearing walls). Design for Disassembly (DfD) is the strategy focussing on the reversibility and disentanglement of constructional components. According to Durmisevic (2006), the degree of disassembly is determined by two component characteristics: their independence and exchangeability. The first is a measure of their entanglement, the latter determines the reversibility of the connections.

These two disassembly criteria can be evaluated using complex relational diagrams. A high number of dependencies between constructional components results in a building that is difficult to transform. Durmisevic (2006) gives the example of an assembly of five components: if all components share connections, the result is a large number of interdependent relations; on the other hand, if four components would be plugged into an intermediary fifth component, the number of relations is minimised.

There is a differentiation between "adaptability" potential of a building and "disassembly" potential. Disassembly potential implies component re-use while adaptability potential implies building re-use. Disassembly relies heavily on a deliberate and optimal sequence of assembly using reversible connections. Building adaptation relies on the "robustness" or "resilience" inherent in a designed building – the ease at which it can adapt to unbalancing changes in its context (Carmona et al. 2010). Because robustness can be introduced by using broad design guidelines, building adaptation is generally easier to achieve. On the other hand, the disassembly potential of a construction oris the key factor determining the re-use potential of the building, its components and the materials they are made of (Durmisevic, 2006). Therefore, this study tries to incorporate both aspects.

The built environment is comprised of various systems – it is the intelligent interface between these systems that allows for greater change by allowing for "disentanglement" of the various building components with minimal disruption and waste. Therefore, the sequence of construction assemblies is important to be taken into account as the process might have to be reversed to access one or other system that needs to be changed. This sequence also needs to be aligned to the higher- to lower- level configurations, implying a progression from more permanent/fixed functions at the higher levels to functions with a higher frequency of change at the lower levels.

SELECTION OF CASE STUDIES

It is important that adaptable approaches to design and delivery are considered for the whole housing market. However, due to the pressing challenge of the South African government to deliver low-cost and affordable housing, the focus of this study is on three projects built for low- to medium- income dwellers. The selected case studies are the K206 and Elangeni, both

in Johannesburg, as well as the Potters' House development in Pretoria. These projects have been selected based on the following criteria:

Typology: the architectural typologies of the projects are different in that a clustered double storey building is considered in the case of K206, allowing for interesting comparisons to be made with a double storey communal development with unique vertical access (Potters' House) and 4-storey walk up blocks with centralised vertical access in the case of Elangeni.

Use: it was also aimed to study buildings that have uses other than single-tenure residential – so the K206 was included due to the fact that it includes rental rooms adjacent to the family unit and Elangeni includes live-work units, both offering opportunities for income generation for the residents. Potter's House includes a communal facility on the ground floor to be used by the residents, who have individual rooms but share ablutions and other facilities.

Form of tenure: the aim was to look at ownership (as is the case of K206) as well as private rental (K206) and social (government-subsidised) rental (Potters' House and Elangeni).

Location: the K206 is a greenfield development in a typical South African black township setting. Elangeni and Potters' House are more centrally located, with Potters' House being an infill project as part of a larger urban regeneration scheme.

ANALYSIS OF HOUSING CASE STUDIES WITH REGARDS TO SUSTAINABLE BUILDING TRANSFORMATION

K206

The K206 project is designed by Anca Szalavicz and was developed as a low-income development in the urban township of Alexandra, Johannesburg. The project forms part of the greater Alexandra Renewal Project (ARP) development. The project aimed to increase housing densities and combines tenure of ownership and rental occupation.

Eight to ten housing units are grouped together, forming smaller clusters of communities around semi-private communal courtyards. Every unit has a 40m² double storey RDP dwelling intended for ownership as well as a 40m² two-bedroom rental unit with ablutions. The total project consists of over a thousand houses. The concept of the project is novel for the township and the inhabitants seem generally happy about the overall project.

Figure 1: *K206, Alexandra, Johannesburg.*

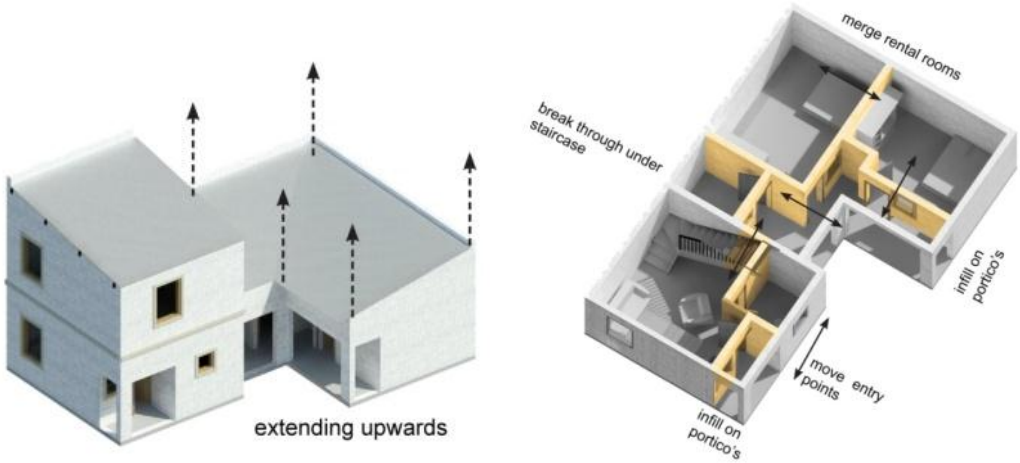
The buildings are constructed from low-cost, conventional and fairly robust materials – an earthy palette of painted and plastered concrete and fly-ash masonry walls covered by mono-pitch corrugated steel roofs with low parapets. On the exterior, the steel-frame windows and first floor concrete floor lines are highlighted with a plaster border and painted white, adding

simple decoration. The entrances to the units have small protective overhangs and the area at the entrance of the unit is intended as a semi-private garden space.

The owners/tenants are allowed to personalise and adapt the buildings within the current building lines. This restriction is imposed for a period of five years. Most residents have added simple security measures to their homes such as burglar-proofing and many have already personalised their units by painting, plastering or tiling the interior or exterior walls, floors, doors and window frames. Some gardens are being planted and some of the external steel doors have been replaced with timber doors. However, alterations to the main spaces would mean having to breakdown load-bearing masonry walls. The internal masonry staircase is robust, plastered and fitted with a simple steel railing. The railing is hinged so to allow furniture to be moved up the staircase. Otherwise, the staircase will not be able to be adapted or moved without making considerable changes to the primary unit; it can only be personalised (by tiling or by removing and changing the steel railings). The current low-cost sanitary fittings may easily be replaced and upgraded.

The simple mono-pitch roof is easy to duplicate, dismantle and re-install. The design would allow harvesting of storm water from the roof but the roof would first have to be fitted with gutters and downpipes which are not currently provided. No provision is made for refuse and washing areas. The existing roof pitches might have to be adapted if solar heaters are to be incorporated in the future – this is a perceived short-coming in the design.

If an external staircase is provided, the rental possibilities can double, or the entire ground floor area could be used as a single dwelling, and the rental tenure moved to the first floor. It would also be possible to move the point of entry to a different location on the same elevation or to a second elevation. Overall, the original structure can be manipulated to some extent but the primary unit itself has very little possibilities for change as it might be a complicated and costly exercise.



Figures2, 3: *K206 general transformation analysis – possible vertical expansion and internal layout variations in the single unit.*

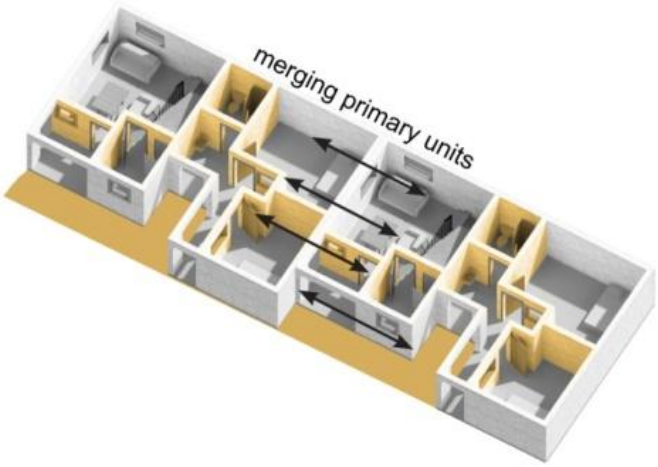


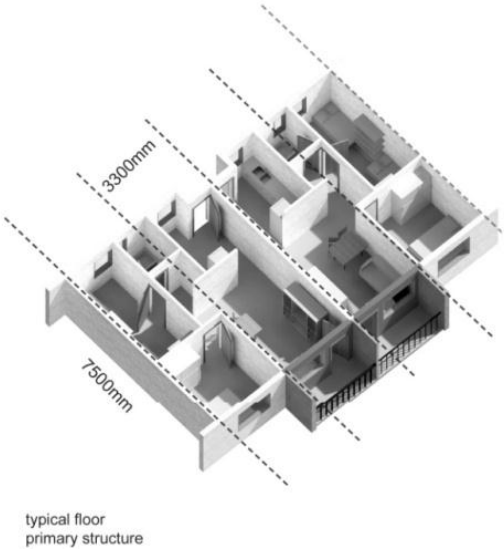
Figure 4: *K206 general transformation analysis – possible merging of primary units.*

It was noticed that material choice and finishes play an important role in the overall experience of the extremely tight spaces. Therefore, by simply having a white wall finish instead of a dark wall finish internally the quality of the space is perceived to be better. The structural system restricts the replacement of the porous masonry, currently a source of great frustration to the residents because of water seepage into the unit. Inadequate divergence of stormwater around the unit, lack of insulation, lack of natural light and cross-ventilation are other shortcomings that might need increased adaptation potential of the units if remedies are to be implemented at a later date.

Elangeni

Elangeni Gardens was designed by the architecture firm Savage+Dodd. The social rental housing project is designed as a medium-rise perimeter block and is located in the heart of Johannesburg. The project is administrated by the Johannesburg Housing Company, JHC, and forms part of the City of Johannesburg's Better Buildings Programme. It was completed in 2002. The total project consists of 168 units, ranging from 35m² one-bedroom units to 59m² two-bedroom units. Other unit typologies are live-work units on the ground floor and loft units on the upper two floors. The building is divided into four main structures, linked by a concrete masonry brise-soleil on the circulation areas, and therefore reads as a single, robust, face-brick complex. The monotony is also broken by extruding shallow balconies, south-facing circulation spaces and general service shafts from the living units. These abutments are then framed with steel frames. The units are designed with stringent economy of space in mind in a typology reminiscent of row-housing – rectangular, narrow and compact.

The housing units are clustered into groups of three units per floor in an attempt to encourage a lifestyle of community living. The corner retail unit and the live-work units face a fairly busy street and filling station. The total project consists of 168 units, ranging from 35m² (one-bedroom) to 59m² (two-bedroom). Most of the rooms and units are adequate enough for either a single person in a single-bedroom unit or two people in a double-bedroom unit. Despite the small areas, young families also occupy some apartments. It is difficult to arrange furniture in the living areas according to the tenant's preferences, making for a very deterministic living arrangement within the unit, but the bedrooms are big enough for some variation. The rooms are well lit and ventilated.



Figures 5, 6: *Elangeni gardens, entrance and structural bays.*

To reduce the overall building costs and ease of maintenance, the materials used throughout the project have been kept to a simple specification. The building is structured in a modular fashion with a grid spacing of 3300mm centre to centre and the units are primarily aligned north-south. The main building structural components are uniform reinforced face-brick masonry walls at a double grid spacing (every 6600mm centre to centre). Steel beams protrude beyond the exterior masonry skins of the units to support concrete balconies, steel staircases or passageways.

There are no ceilings fitted except on the loft units. Bathrooms and kitchens are tiled and the original carpets in the living and bedroom areas are also gradually being replaced with tiles. The built-in cupboards in the bedrooms have been removed and replaced with just a rail and in some cases a small shelf. On the stair landings, behind the brise-soleil screens, there are small enclosed yards for hanging washing. There are no solar water heaters nor is there any water collection from the roof. The building does not have recycling amenities but provides a standard refuse yard for waste disposal.

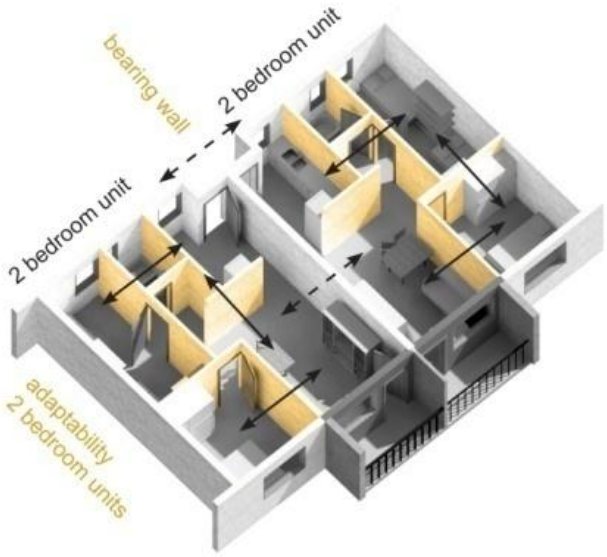
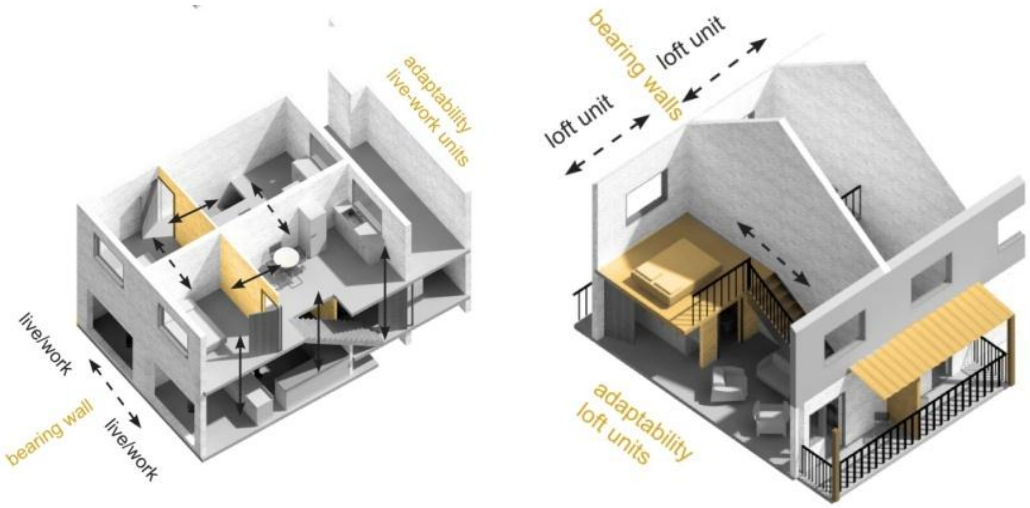


Figure 7: *Diagrammatic analysis of Elangeni Gardens*



Figures 9: *More diagrammatic analysis of Elangeni Gardens.*

The overall design and layout of the building would not allow for much adaptation or extensions beyond the current building lines. The scheme can accommodate some internal adaptations that the tenants could implement themselves, but these changes appear to be limited to the two-bedroom units. Expanding the area or merging of units requires the breakdown of bearing walls. However, it is noted that adaptability potential relates to the section of the building being considered, as some units are perceived to be easier to adapt due to differing structural and spatial features. The need to design singular units within the narrow grid spacing results in a tight fit of entrances and wet services while units that span over the double grid might offer more potential for flexibility.

In accordance with the architect's general policy to designing for efficient maintenance, the unit materials, detailing and components provide relatively low maintenance requirements to fit the economic profile of the target group.

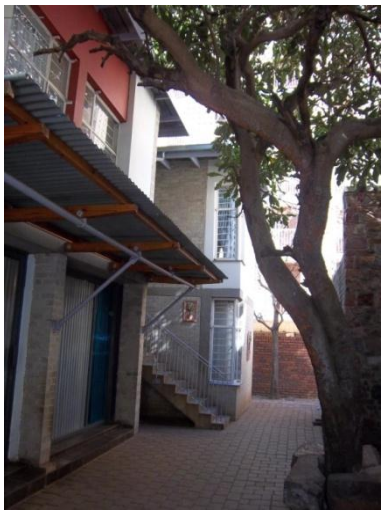
Potters' House

The Potters' House is situated in Burgers Park Lane, Pretoria city centre. The project provides various housing options mostly for people in need of shelter, social support and economic upliftment. The concept was developed by the Consortium for Urban Transformation (CUT), IDASA, the Centre for Housing and Land Development at the University of Pretoria. Burgers Park Village is conceived as an urban rejuvenation project involving the recycling of old buildings. Potters' House is a part of the Jubilee Centre mixed-use complex from which Yeast City Housing administrates the overall project. Established in 1993, the building provides rental tenure and is a transitional housing facility for women in need. It forms a part of a greater community of buildings and small courtyards and is situated behind the main office building. The exterior spaces are perceived to be relaxed, safe and calm and the interior spaces are simple and efficient. However, while the buildings are cool and protected during the summer, tenants report that the winters are very cold.

Potters' House has a symmetrical design in an H-shape formation and the ground floor has a central living-room area with large swivel doors. The ground floor units have a semi-private garden space that can be directly accessed from the northern rooms through steel-framed glass doors. This is quite a pleasant area, but the nature of the tenure means that the garden space is not well-maintained.

The building accommodates 25 bed spaces in 10 rooms. The 24m² units have simple longitudinal layouts, with one room at each end with ablutions in the middle. All the interior walls within the units have a clerestory window. The rooms are well-lit but the bathrooms are fairly dark, with the electric lights kept on most of the time. The rooms in themselves can be passively ventilated and windows are well placed for natural cross-ventilation. All the wet-service shafts are located on the exterior of the building and covered with long strips of corrugated sheets. Most entry points on the ground floor usually have a stepped threshold and entrances are covered and protected from the elements. The rooms have insulated ceilings. Every room has a simple built-in cupboard.

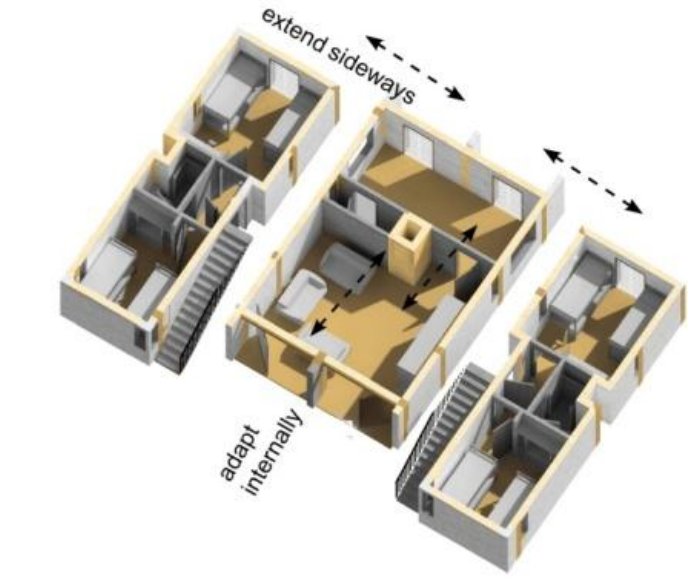
The two-storey building is a hybrid structure with a reinforced concrete frame on the ground floor with load-bearing concrete masonry on the upper level. The exterior surfaces are mostly covered in concrete or clay pavers. The building is robust and upkeep is low. The building has three insulated, corrugated steel sheet roofs on timber rafters, each fitted with gutters and downpipes. The building is fitted with steel-frame glass windows and primarily hollow-core doors.



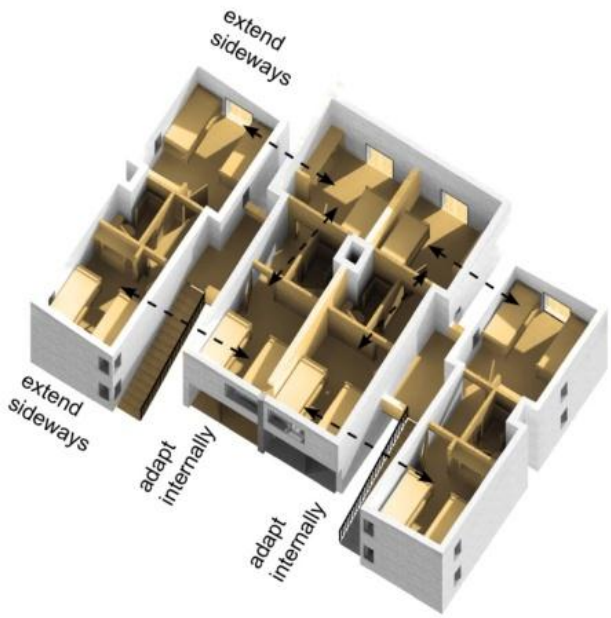

Figures 10, 11: *Views of Potters' House.*

The majority of the building exterior is unplastered, but the interior spaces are plastered, painted or tiled according to the occupation. The nature of tenure in the building mean that more significant changes, additions or extensions would have to be implemented by the Yeast City Housing company. The simple frame on the ground floor makes changes at that level relatively easy. The centrally located ablution areas might restrict adaptation to some extent. However, this same positioning of the wet-core offers various opportunities in the central block of the building. The two flanking rooms on each floor are difficult to merge, but the rooms could be adapted to change from a two bedroom unit to a self-contained one-bedroom unit on the south and a north-facing living area.

Due to the placing of passages and doorways, a room from one unit would be able to merge into the opposite unit in an L-formation, or across the entire building. By inserting an opening into a wall, it is possible to merge an entire floor completely without making significant variations to the building's appearance or structure. As a whole, it would be possible to extend the building upwards by two or three storeys, depending on the foundations provided.



ground floor
basic frame



typical floor
frame and infill

Figures 12, 13: *Analysis of Potters' House.*

General upgrading of finishes would be possible as would retro-fitting sustainability features. The ground floor area could also merge with the first floor and become a duplex or larger independent unit. It could also become one large unit with the northern portion of the building, or in contrast be divided into two smaller units as the structure would not be influenced by these adaptations. The covered exterior cast in-situ concrete staircases allows that the building can be almost decapitated from the first floor and something completely new can be built without change in the basic structure at ground floor level.

SUMMARY OF FINDINGS AND COMPILATION OF ASSESSMENT CRITERIA

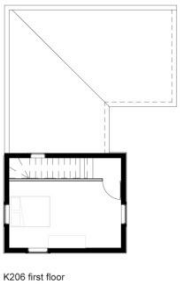
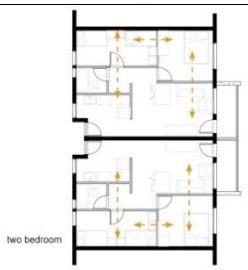
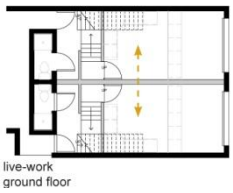
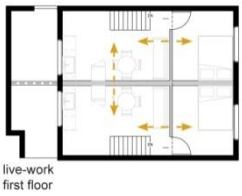
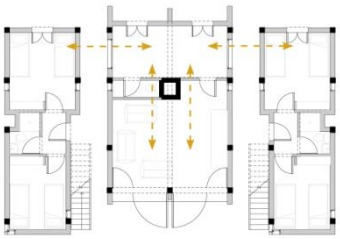
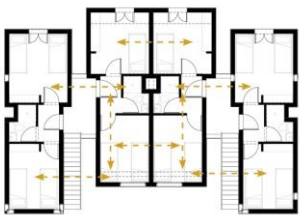
	First level	Second level	Comments on adaptability potential
K206	 K206 ground floor	 K206 first floor	-Semi-private threshold space is easily enclosed -House may be extended upwards over the two rental rooms -The two rental rooms may be merged with the primary unit – however this means losing the threshold and creating an awkward passage in one scenario or breaking down a structural wall, under the stairs, in another
Elangeni 1-bedroom	 one bedroom L-shape		-Narrow grid spacing and structural walls limit the interior alteration possibilities -However, with some effort and wastage it is possible to create an open plan in one unit or merge two units by removing a wall and adding structural support
Elangeni 2-bedrooms	 two bedroom		-This unit provides real possibilities for major changes due to the large spans and non-structural walls -The balcony spaces can be built-up adding on average 4m² of space, but this entails removal of doors and walls and does not add much value to the quality of the space
Elangeni live/work	 live-work ground floor	 live-work first floor	-The small areas limit the interior alteration possibilities of the unit but the non-structural walls allow possible merging of two units
Potters' House	 ground floor not to scale	 first floor not to scale	-Frame and infill at ground floor allows for easy changes, however the hybrid structural system poses restrictions on the adaptability potential of the structure as a whole -Central space with central wet core allows for more change and combination possibilities -While there are restrictions to extension beyond current building lines, it is not impossible to do so, especially if the building is to be linked to the surrounding buildings

Table 1: *A summary and general comparison of the plans of the selected projects. It must be noted that this information has been compiled from available drawings and documents and still needs to be verified by the architects in some cases.*

Based on the case studies, several features of the buildings are already undergoing change, by the owners or social housing institutions, with no professional input and no requirement for complex approval processes. These are therefore assessed as being easier to modify, adapt or change. These features with "easy adaptation" potential are also perceived to have high social value in some cases (such as the replacement of steel doors with timber doors in the K206) and high functional value in others (such as the incorporation of theft- and vandal- proof features in Elangeni as well as easier-to-maintain tiles as opposed to the original carpets).

While some features may have social as well as functional value, it is perceived that some features which will truly enhance functional performance are more difficult to implement as these would involve spatial alterations and the disruption of major building components which implies higher technical impact. Some high level adaptations, such as changing the facades may also have a high level of social impact, especially when a facade is considered low quality as is the case the K206. In this project a facade material change implies breaking down a structural wall.

However, it should also be remembered that the components that undergo frequent change and that are easier in a technical sense to change, may also have very high environmental impact if re-use potential, disposal options and embodied energy aspects are taken into account. "Easy adaptation" may thus encourage greater "frequency of adaptation" resulting in higher environmental costs.

From this discussion, the assessment of adaptability potential may be carried out based on features that are easier to adapt to those that pose greater difficulty and have higher impact. Frequency of adaptation is here linked to the degree of ease or difficulty of adaption:

Easy adaptation
Easy adaptations are usually short-term changes in that they deal with changing the appearance of units and (regular) maintenance work. They benefit the users (have high social value) because they could be used to increase the uniqueness of the occupied unit (use, colour, finishes). The assessment of short-term adaptability depends on architectural analysis (multi-functionality of the plan layout) and housing regulations (to what extent users are allowed to make changes). Examples are:

- changing doors (without changing the door opening) (referred to as an "independent component")
- removing carpets, paving, tiling, painting (functional- or status- linked "finishes")
- adding burglar bars ("independent component")
- add features such as solar heating or rainwater collection (general fittings also as "independent components")

Moderate adaptation
Moderate adaptations are generally medium-term frequency and generally include those changes needed to update a building to changing market demands or government requirements, e.g. replacing or upgrading finishes, increasing or decreasing unit sizes to match evolutions in demography, updating the unit layout and services according to changing societal standards, etc. The feasibility of these kinds of changes can usually be assessed by analysing the structure and construction of the building, and the degree of entanglement of constructional components and functions. Because moderate adaptation is done on the level of building components, improving the adaptable capacity on this level strongly influences the other levels. Examples:

- reconfiguring internal layouts (this implies knocking down an "internal non-structural wall")
- reconfigure internal vertical or horizontal circulation ("private circulation")

- adjust a partially-enclosed space or change a point of entry (change “building envelope” or “openings”)

Intensive adaptation

These intensive changes in a building usually only happen in the long-term and only become viable when entire buildings or projects need to be refurbished. They include elaborate adaptations like vertical unit extensions (i.e. through an existing floor slab), horizontal unit extensions using new structures or cantilevers and changing the typology of outside circulation. Long-term changes require analysis and design done by architects and structural engineers. Examples:

- reconfiguring internal layouts (knocking down an “internal structural wall”)

- expand vertically and horizontally (which implies adjusting various “system-dependent components” which are governed by the location of higher-order systems such as the “wet services” and “vertical service cores” as well as “communal vertical or horizontal circulation” areas which are more complex to change, not only for technical reasons but also because they are shared areas where a group decision needs to be taken as compared to “internal circulation” where individuals take the decision)

The transformational capacity of a building is, of course, largely determined by the building itself. As most aspects of adaptability come into play when trying to implement moderate/medium-term changes, it could be argued that this intermediate phase is the most important. The feasibility of medium-term changes is based on the complexity of the construction (whether components are functionally independent or interdependent) and can be assessed by the degree of professional involvement necessary to implement the changes.

ADAPTABILITY ASSESSMENT TOOL

From the above it can be seen that, while the existing housing projects do not appear to have been designed with adaptation potential as a high priority, this does not imply that they can’t be adapted. An approach to assess the adaptable capacity of the existing housing projects is thus attempted.

This paper presents a broad, rather than in-depth, assessment of the selected case studies. As the projects under assessment were not designed to be adaptable, an in-depth analysis of the disassembly options of the existing construction would most likely result in low scores for all projects and would be unnecessarily time-consuming. The priority is a general assessment of the adaptability potential, rather than a detailed analysis of every aspect of disassembly or re-use of the construction and its components. This makes assessment more straight-forward, and requires a lower level of expertise.

The outcome of this process has been a list of possible adaptations and comparisons between buildings with regards to the ease with which these adaptations may be achieved. In order to be directly usable for housing practitioners, the presented tool lists possible adaptations, impact on other features/components of the building and categorises these ranging from easy to intensive adaption potential. The tool theoretically allows for scoring and computation, though this is to be done in the future and has not yet been achieved.

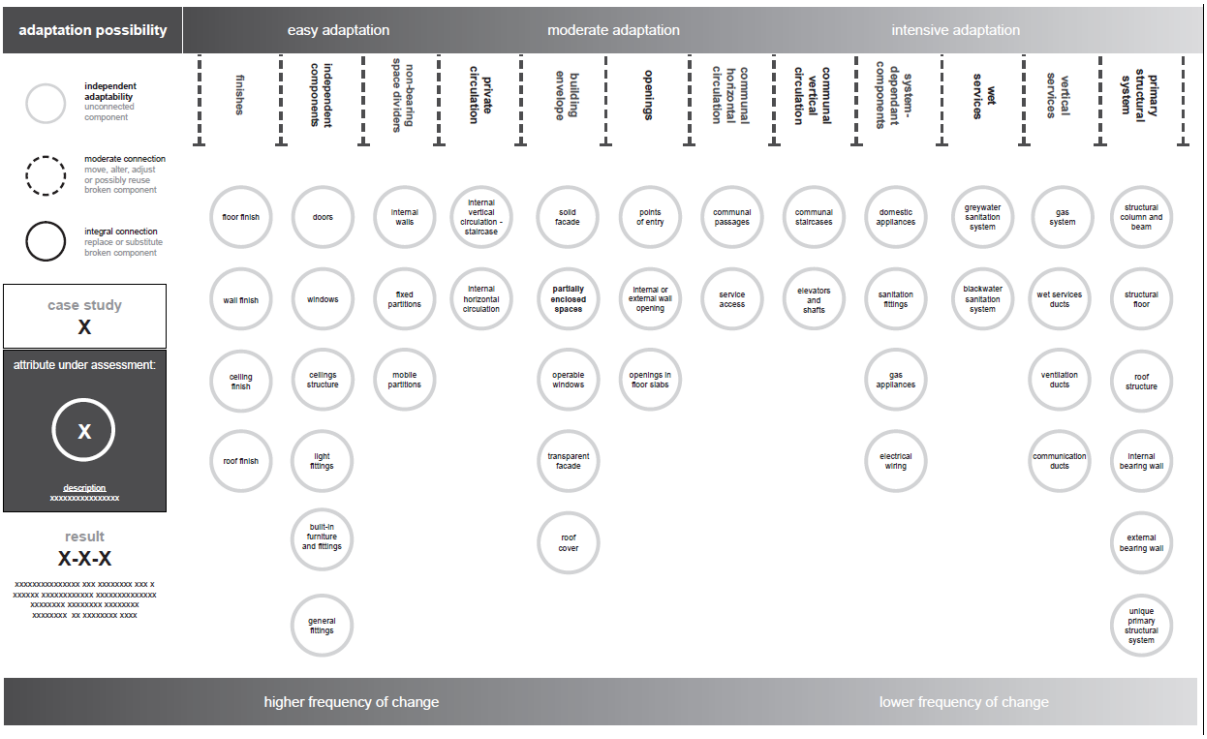
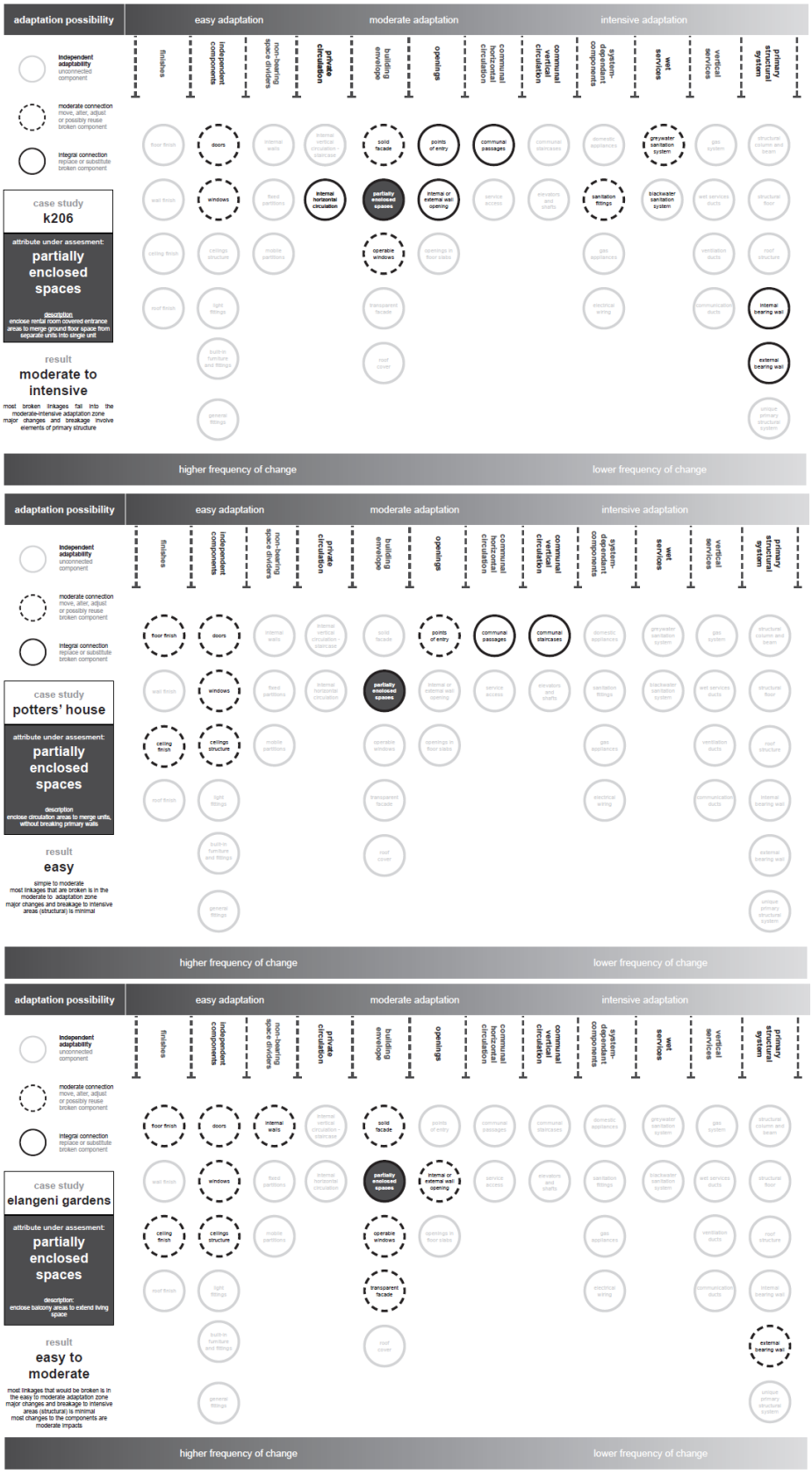


Figure 14: *The format of the assessment table.*

Currently, it is intended to simply present when change in an attribute of a building component breaks or serious alters another component/s, when there is possibility of re-using removed components, when a component can be removed and substituted without breaking anything else and when there is absolutely no impact on other components. Thus, the degree of entanglement is assessed by the number of features/components affected indicated by the number of circles on the diagram that are marked in a grey, dotted or black circle – this indicating the degree of damage to attached features/components.

A more in-depth tool might differentiate between an adaptability rating, disassembly rating or reuse of components rating and it would also incorporate aspects such as owners/users behaviour and preferences. A more complex and accurate assessment would also separate between unit adaptability and building adaptability.

Rating and comparison between projects may be achieved by assessing the number of aspects of a building affected by the same change in attributes in the buildings being compared. The number of affected circles on the table (building components/features) determines the degree of entanglement of the attribute under assessment. The more affected circles on the right side of the table, the more difficult it is to adjust that particular aspect of the building. These relations and their degree of entanglement may ultimately be scored.



Figures 15, 16, 17: *Application of assessment to the three case studies.*

DISCUSSION

The capacity for sustainable building transformation has been assessed by studying the internal planning, construction methods and material selection of some case studies. Some results of this study may be presented as follows:

- Simple column and beam structures offer more opportunity for change when compared to load-bearing masonry
- Alternative technologies (sandbag construction, adobe construction, or bamboo-reinforced concrete masonry) could be even more cost-effective and should be investigated
- If not the entire structure, perhaps only one or two walls can be considered with alternative materials to counteract some site specific issues such as drainage or heat gain or allow for a more varied potential in adaptability of the building.
- Narrow grids limit spatial manipulation, especially when the bays are separated by structural walls
- Variation in the grid may allow for a variety of spatial experiences and areas according to preferred taste and need
- Open plans allow for varied interpretations; this may also be investigated vertically with a structural system over two floors instead of per floor
- Alternative building components should be considered to demarcate spaces in the double grid units, such as adaptable composite panelling structures or the use of mobile storage units

It should be noted that this list is used as an example and is not intended to be exhaustive. It has also not considered the cost implications of this approach – however, it is believed that the long-term financial and environmental cost implications of not taking adaptability into account are is very high – especially when a building has to be completely demolished with no possibility to dismantle components for re-use.

We therefore proceeded to develop an assessment tool to study possible adaptation in more detail. While this has been described as “broad” rather than “in-depth” assessment, a preliminary conceptual tool is presented to allow for further comparisons between projects with regards to adaptability potential.

CONCLUSION

By studying existing housing projects, it has been possible to develop an approach to assessing the potential for adaptability as well as to offer some guidelines for new projects. This research intends to contribute to the debate on transformable structures and to raise awareness on the topic. The proposed assessment tool may be used by designers or project managers increase their comprehension of basic concepts of transformability and disentanglement of functional layers. Hopefully, it will show that sometimes only small changes are required to drastically increase the future options available to a project that needs to be renovated. Once the tool is further developed, the intention is to use it in the field and to get input from professionals. While the ultimate aim is to develop a design guide, this would

require a greater level of detail planned for another stage of this research project. This design guide will aim to influence thinking, design and planned delivery approaches at the conceptual stages. It is concluded that this approach to design is highly relevant to the South African context and deserves serious attention in the building of future housing projects.

NOTE

All photographs were taken by Calayde Davey or Amira Osman, all models/graphics are drawn by Calayde Davey and sources for plans were either the architects themselves or they were sourced from ASA and Yeast.

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