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TRANSFORMATION OF PUBLIC HOUSING BY RESIDENTS

An analysis of spatial patterns and morphological genotypes in Kaduna, northwest Nigeria

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ABSTRACT

Transformation of public housing by homeowners is a well-documented phenomenon in developing countries, Nigeria inclusive. Few studies systematically analyse spatial and morphological patterns which emerge from user perspectives and residents' lived-in experiences as a means of informing designs in future. The lack of such vital feedback is proffered as a major cause of failures observed in housing programs. This study employs architectural data from measured surveys and Space Syntax analyses of 26 modified units in Malali, Kaduna within northwest Nigeria to bridge this gap. Results reveal that spatially, ensuite toilets/bathrooms as well as bedrooms were the most added spaces, averaging four (4) each per dwelling. Convex map analyses illustrate that on average, modified houses are more integrated (H^* 0.72) than the original prototype (H^* 0.52). Five genotypes emerged from user transformations, the largest group displaying morphological characteristics of the original prototype. Others combine characteristics of open-courtyards and self-contained bungalows, a legacy of British colonialism. Genotype 5 emerged as the most satisfactory genotype containing houses with family sitting rooms being the most integrated spaces. Consequently, satisfaction in the study context is associated with enclosed, secure and well-integrated living spaces directly connected to open courtyards as well as other service and private spaces. Results imply that future prototypes must be flexible enough to accommodate up to four bedrooms, each attached to ensuite toilets and bathrooms. Architects also need to pay special attention to the design of prototype units as transformed houses sharing similar morphological characteristics with the original prototype recorded low satisfaction ratings.

KEYWORDS

Morphological genotypes, Nigeria, Satisfaction, Public Housing, Transformation

1 INTRODUCTION

The Federal Government of Nigeria (FGN) invests heavily in the design and development of public housing. Okonkwo, et al.,(2012) report that between 1991 and 2006, about ₦21.18 billion was expended on public housing development. In 2020, ₦317 billion was earmarked to construct 25,515 homes nationwide during the COVID-19 pandemic (FGN, 2020). Subsequently, ₦404 billion was allocated to the Ministry of Works and Housing, making it the highest allocation in the 2021 budget proposal (Fadare, 2020). Despite such massive investments, houses within public estates eventually undergo enormous transformation by end-users, implying the lack of attainment of optimum value for amounts originally spent. Although several studies investigate transformation of prototype public housing in the Nigerian context (Morakinyo, et al., 2018; Aduwo & Ibem, 2017; Isah, 2016; Ilesanmi, et al., 2015; Adedayo, 2012; Adegbehingbe, 2011), research has been limited to the documentation and classification of modifications and their impact on the environment with little spatial investigations to aid design professionals notably architects, engineers, builders, surveyors, urban planners and policy makers improve upon similar housing developments in future. Specifically, literature presents no empirical exploration regarding the spatial and morphological varieties of designs which emerge from residents' lived-in experiences following transformation of public housing units in Nigeria. Such an investigation is critical towards informing and guiding design from the inception of projects as crucial decisions are often based on assumptions made by professionals' experience and intuition (Aragones, et al., 2017) rather than on user experiences and feedback. This has been proffered as a reason for the failure of previous public housing programs in the country.

The current study investigates spatial patterns and morphological genotypes which emerge from the transformation of public housing units by residents in the Nigerian context. The aim is to improve design decisions of similar housing projects in future. Public housing refers to housing originally constructed or procured using public funds.

The paper is organised in five sections following this introduction. The literature reviews research on design and planning aspects of transformation in section two and the Space Syntax methodology employed in section three. Results from the investigation and discussion of findings follow in section four. The paper concludes with recommendations and references in sections five and six respectively.

2 LITERATURE REVIEW

Literature on transformation in public housing covers a variety of themes. These include patterns of transformation, motivating factors, processes, resources deployed, challenges encountered as well as satisfaction levels of residents. The literature on design and planning aspects of transformation is however described in terms of spatial patterns and morphological genotypes (Table 1). The latter largely emanate from Space Syntax research.

Table 1: Summary of transformation studies on design and planning

Author(s)	Aim	Key findings
Spatial patterns		
Morakinyo, et al. (2018)	To evaluate patterns of transformations of dwelling units	Semi-public areas notably sitting rooms received the most transformative efforts (surface, slight and spatial modifications) followed by bedrooms (private spaces), outdoor spaces, kitchens, dining rooms and stores
Aryani, et al. (2017)	To discuss design transformation of public housing units occupied for short periods	Private and semi-private zones were most transformed; public zones were the only non-transformed areas. Semi-public zone usually covered entire rear sections of plots
Aduwo & Ibem (2017)	To investigate housing transformation in government constructed residential estates	Addition of bedrooms was the most prevalent transformation followed by construction of perimeter fencing, addition of shops and worship places. Addition of burglary proofing to doors and windows recorded the least frequency
Natakun & O'Brien (2009)	To explore ways residents undertake modifications and to identify common patterns of modifications	6 modification patterns were identified-paving around dwelling perimeters, improved fencing, extended eaves, roofs and awnings covering open spaces, enlarging indoor public spaces via front porches, extending kitchens via rear porches as well as addition of rooms
Shiferaw (1998)	To investigate user transformed dwelling units	Transformation trends include extending spaces within the plot, formation of accesses and subdivision of outdoor spaces. Extensions were zoned horizontally
Morphological classifications and genotypes		
De Franca, et al. (2019)	To identify differences made by residents from original proposals	IVs increased after modifications. Circulation spaces, living rooms and kitchens became the most integrated spaces, reinforcing sectors and separating private and public spaces
De Franca, et al. (2017)	To understand if inhabitants adopted the original proposal or if modifications reveal another genotype	Living rooms, kitchens, circulation (social spaces) were the most integrated spaces. Zoning divides systems into 2 following traditional Brazilian houses different from the tri-partite middle-class model. JPGs reveal deep tree-like non-distributive, non-integrated hierarchical configurations. Only 3 houses had rings
Bessioud & Mazouz (2017)	To compare changes between old and new houses	Circulation spaces separate public (integrated) and private life (segregated) spaces. Courtyards became more segregated with the introduction of private courtyards where domestic activities occur
Moreira & Serdoura (2017)	To assess units as designed and lived-in in order to understand differences enabling better living conditions	Circulation and transition spaces were the most integrated spaces. Most satisfactory designs segregated private spaces and integrated social spaces. Dissatisfaction was evident when this priority was not in place
Isah (2016)	To relate the configuration patterns and identify features of user-initiated changes in public housing	Transformation categories identified include conversions, extensions, additions, complete transformation and reconfigurations. JPGs of modified units reveal the adoption of traditional configurations in favour of socio-cultural values
Maina (2013)	To examine possible reasons behind the modification of prototype housing units	Courtyards and living rooms were the most integrated spaces and were shallow in depth from the outside. H^* of 0.70 was similar to the 2nd genotype of the community sample suggesting that residents modified dwellings based on socio-cultural values
Reis (2003)	To explore how converted social housing has been spatially configured and its	5 spatial patterns were identified-original houses; transformations with no isolated extensions in the backyard; original unit with isolated extensions in the backyard; transformed unit with isolated extensions and

Author(s)	Aim	Key findings
	effect on residents' satisfaction	2 stories modified with no isolated extensions. Most converted houses exerted higher control of movement and on average had higher IVs compared to the original prototype. Original dwelling configuration and plot size presented areas of low satisfaction after transformation
De Guzman, et al. (2001)	To provide base studies for future development of collective housing	Limitations of unit design did not prevent variations in space re-design by residents. Equipment and furniture were employed to separate space use. JPG reveal tree-like asymmetric patterns. Dining/kitchens were most integrated, controlling movement. Living rooms serve as transition spaces
Tipple (2000)	To describe and compare characteristics of transformation in 4 study areas-Bangladesh, Ghana, Egypt and Zimbabwe	Internally modified plans demonstrate more sensitivity to local cultures than original designs. JPGs reveal shallow, often symmetrical integrated plans supporting inward-looking rooms which open directly off open spaces/corridors reminiscent of traditional compounds. Transformations in multi-story buildings were dependent and restricted by original plans

2.1 Spatial patterns

Studies on spatial or geometric patterns of transformation describe changes using the most basic design tools-bubble diagrams, organisational schema or zoning arrangements universally understood by design professionals to represent functions and activities within dwellings. These are often presented in terms of private, semi-private/service and public/social zones. Aryani, et al. (2017) compared zoning patterns of initial and transformed prototype units within narrow plots. The authors note that extensions to the rear and sides of plots account for the most frequently occurring transformations with greater priority placed on private and service zones. The latter were typically kitchens and cooking areas. Shiferaw (1998) likewise reported that socio-cultural, hygienic and climatic factors influenced changes in locating cooking areas to the rear of plots or out of direct vision by creating accesses which prevent entry through the main house. Nonetheless, several studies describe transformations in terms of modifications to building components and features within functional spaces (Morakinyo, et al., 2018; Aduwo & Ibem, 2017; Natakun & O'Brien, 2009). These include changes to fences, doors and windows, cabinets, fittings and fixtures, floors, ceilings, extension to porches, addition of bedrooms, shops as well as worship places (Table 1).

2.2 Morphological genotypes

Morphological categories and genotypes largely emerge from Space Syntax literature. These build upon generalisations of spatial patterns using Justified Permeability Graphs (JPG), Convex map analyses, Visibility Graph Analyses (VGA) and inequality genotype computations (H^*) to describe topological relationships between functional spaces as well as to infer genotypes which emerge from the transformation of dwellings. An important configurational property from syntactic analysis is integration, a measure of the minimum number of intervening spaces which must be crossed in order to reach all spaces within a system (Reis, 2003). The integration value (IV) is a numerical figure calculated for each space within a complex as an expression of the extent to which that space integrates or organises access and movement and by implication social network and activity within the complex (Maina, 2013). It is an index defining the degree of inter-relations between functional spaces in a building, house or system (De Franca et. al, 2019). Hanson (1998) remarked that integration has emerged as one of the fundamental ways houses convey culture through their configuration. A closely related measure to integration is depth from the exterior or root node. This expresses the topological distance inhabitants and visitors encounter while approaching and navigating spaces within a system (Amorim, 1997). Depth describes the topological distance measured by the number of convex spaces which separate all others in a system and the relationship of the spaces to the exterior (De Franca et. al, 2019). The inequality genotype, H^* describes a statistically stable pattern of variation of IVs across a given rank order of convex spaces in a system (Bafna, 2001). When the sequence of IVs in a locality differ in a similar pattern, then a genotype likely exists. H^* is often computed using the difference factor, an entropy-based measure (Hillier et. al, 1987). Together, measures from Space Syntax analyses display configurational characteristics of spatial arrangements based on objective computations which would otherwise not be apparent from observations of geometric properties of the systems. These have been beneficial in uncovering similarities and differences in building organisation and planning among dwellings within similar or different contexts (Bessioud & Mazouz, 2017; Muhammad-Oumar, 1997; Hanson, 1998).

Topological studies on transformation present a wide variety of findings depending on the study focus and context as illustrated in Table 1. Three (3) common trends however emerge from the literature. These are increase in integration especially for public, social and circulation spaces; control and increase in depth for modified systems as well as the impact of the local culture and original design on transformations made by residents.

De Franca, et al. (2019) describe post-modified systems evaluated from transformation of public houisng in Brazil as being more integrated due to the creation of rings through living rooms, kitchens and external areas while maintaining the same depth as the original design. Circulation spaces played vital roles in breaking up systems into social (public) and intimate (private) zones. Consequently, these turned out to be the most integrated spaces. Similar observations were proferred by Bessioud and Mazouz (2017) as well as Moreira and Serdoura (2017) from investigating modified dwellings in Tunisia and Portugal respectively. In their syntactic study of old and newly-constructed government dwellings in Douiret village, Bessioud and Mazouz (2017) revealed that the creation of distribution spaces, notably a series of connected courtyards, seperated public and private areas while ensuring the sustainability of traditions linked to the domestic life of inhabitants. Comparing several typologies of apartment floor plans, Moreira and Serdoura (2017) also note that circulation spaces increased the integration quality of systems especially when located within rings. This ensured that circulation and transition spaces emerged as the most integrated space within the houses. The authors assert that the optimum organisation of functional spaces from residents' point of view was achieved when configurations integrated living areas and segregated private ones. They conclude that modifications were bound to occur when social/living spaces were partly segregated. A syntactic consequence of seperating public and private domains using circulation spaces is often an increase in depth and control of movement. De Franca, et al., (2019) however note that rings within a complex mediate depth increase.

In contrast to the aforementioned studies, Reis (2003) observed that converted houses from a sample in Brazil exerted higher control over movement than original prototypes. This was influenced by changes in the socio-cultural values of residents and the original design of prototype units. The latter is an observation supported by several studies where design and planning of original prototypes influenced the way residents transformed their houses (Aryani et al., 2017; Suleman, 2012; Natakun & O'Brien, 2009; Reis, 2003; Carmon, 2002). Tipple's report of transformations across public housing in four countries demonstrates that the internal planning of modified dwellings revealed greater sensitivity to local cultures compared to the original designs. JPGs presented shallow, often symmetrical integrated systems supporting inward looking rooms that were likely to open off courtyards or circulation spaces, notably corridors (Tipple, 2000). This is typical of configurations found within traditional compounds especially in developing countries such as Bangladesh, Ghana and Zimbabwe where the samples originated from. In Egypt, transformations depended on original floor plans largely because of restrictions imposed by the design of multi-storey units.

Few studies report satisfaction levels of residents following transformations. By comparing transformations made by satisfied residents resettled in new dwellings with floor plans of old traditional dwellings of Douiret village, Bessioud and Mazouz (2017) inferred stable patterns of organisation between the two sets of dwellings. This suggests that satisfaction is most achieved when modern dwellings conform to the socio-cultural values of inhabitants, a theme that resonates across the literature (Isah, 2016; Maina, 2013; Natakun & O'Brien, 2009; Tipple, 2000; Shiferaw, 1998). Satisfaction by residents was also achieved when private spaces were segregated and social spaces integrated (Moreira & Serdoura, 2017). Evidence also exists to illustrate that transformation does not always result in satisfaction or place attachement. Reis (2003) reports that a number of residents opted to move out of a neighbourhood if the opportunity presented itself. This suggests that the relationship between satisfaction and transformation is a complex one. It is also likely mediated by other factors depending on study contexts.

In sum, literature reviewed illustrates common spatial and morphological patterns related to transformation within public housing. In line with the aim of the current study, the following research questions are posed:

- Which spatial patterns exist within transformed public dwelling units in northern Nigeria?
- Which morphological genotypes emerge from syntactic analyses of transformed housing units in northern Nigeria?

- Which are the most satisfactory genotypes to inform future design and planning of public housing in the study area?

These questions are investigated using a sample of transformed lowcost public houses in Malali, Kaduna, northwest Nigeria.

3 DATASETS AND METHODS

3.1 Study area

Built by the Nigerian government to host participants and guests of the 2nd Festival of Arts and Culture (FESTAC) in January 1977, the Malali Housing Estate was handed over to the Kaduna State Housing Authority (KSDPC) in March of the following year (Suleman, 2012). Kaduna is the former capital of the defunct Northern region and presently the State capital of Kaduna State, centrally located within northwest Nigeria as illustrated in Figure 1. Initially conceptualised as a rental scheme, houses in Malali Housing Estate were eventually converted to an owner-occupier scheme where homeowners were free to modify their units following payment of the full premium. The estate originally contained 608 houses, 218 of which were one-bedroom units, 288 two-bedroom semi-detached units and 155 three-bedroom units (Figure 1).

The current study targeted a quarter (72) of the two-bedroom semi-detached units as two-bedroom typologies are arguably the most constructed prototype public housing units in the Nigerian context and therefore the typology frequently prone to transformations.

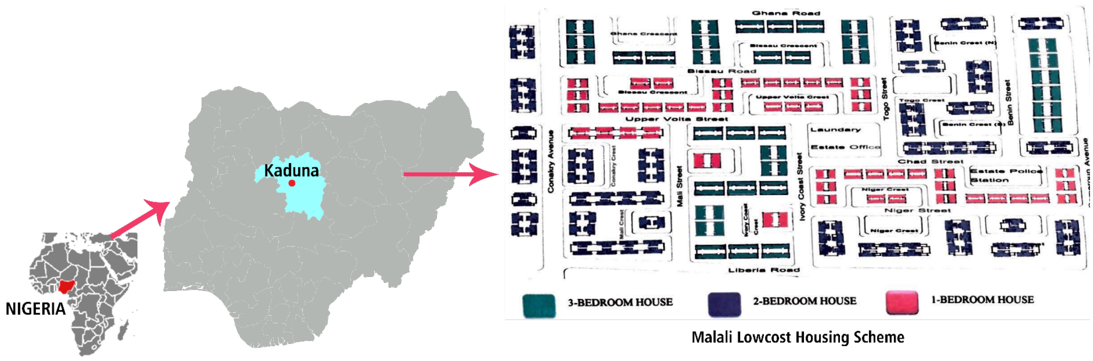

Figure 1: Study location. Adapted from Suleman (2012) and Google images

Original two-bedroom houses in Malali contain two bedrooms, a sitting/living room, kitchen, toilet, bathroom, store and open courtyard (Figure 2). The houses were constructed of cement blocks and finished with cement-sand screed on the walls and floors. The original roofs were covered with corrugated galvanised iron sheets while doors and windows were designed as one-sided swing steel frames in-laid with glass panels.

Overall, the floor plan displays aspects of the traditional lifestyle of many cultures in northern Nigeria where the focus of everyday life is the open courtyard, an inward-looking space. Traditionally, sleeping and cooking rooms as well as granaries, reception huts and service areas are all arranged around open courtyards (Saad & Ogunsusi, 1996). This arrangement fostered communal living between members of nuclear and extended families, a common practice in traditional societies within the region. The original typology is therefore a compromise of modern constructed rooms arranged on two sides of an open courtyard illustrated in the floor plan of the original two-bedroom semi-detached prototype in Figure 2.

3.2 Dataset and analyses

We employed a mixed methodology comprising of a measured and questionnaire survey to address the aim of the study. The measured survey involved a documentation of 26 transformed dwellings in the study area, having secured the consent of individual household heads or their representatives. Data collected for spatial transformations included modified housing characteristics and construction materials as well as spaces. These are presented in Figure 2 and Table 3 and address the first research question. Scaled floor plans of the original and transformed houses were employed to compute syntactic data instrumental for inferring morphological genotypes to address research question two. JPGs were developed using the exterior space as root node (Level 0). These illustrate access and route choice into the houses (Figure 3). Furthermore, floor plans of original and transformed houses were exported to Depthmap X following standard procedures for convex map analysis (Al_Sayed, et al., 2014). IVs generated were employed to compute average mean depths and H^* for each of the dwellings using the algorithm presented by Hillier et. al, (1987). Together, syntactic measures were employed to establish genotypes across the sample. Results from these analyses are presented in Table 4 and the Appendix.

The questionnaire provided demographic data as well satisfaction ratings of residents. Demographic data in the first section of the questionnaire focused on gender, marital status, highest education level and age of household heads. Other demographic variables were household income, length of stay or residency period, household size as well as tenure status. Two of the questionnaires were invalid. Results presented in Table 2 were therefore based on responses from 24 households. The second section required respondents to rate their satisfaction with functional spaces, specifically bedrooms, toilets, bathrooms, sitting rooms, courtyards, verandas, kitchens, stores as well as corridors within the transformed dwellings. Ratings were evaluated using likert scales from 1 (very dissatisfied) to 4 (very satisfied). Results from this analysis are presented in Table 5. Overall mean score for each household was computed as the average of all scores across functional spaces. These were instrumental in establishing the most satisfactory genotype presented in Table 6 in response to research question three.

4 RESULTS

4.1 Demographics and transformed housing characteristics

Results from the demographic section reveals that our data generally conforms to the profile of residents occupying public housing in northern Nigeria from similar studies (Maina et al., 2021). Household heads were on average male, married, university educated and employed (Table 2). Average household size of 5.71 was however slightly above the national average of 4.9 expected of households in urban areas of the country. Although half of the sample own their homes, average residency was 8.5 years. This figure is slightly lower than the 10 years residency boundary expected for commencement of transformation by residents within public housing (Aduwo & Ibem, 2017). Income was reported by less than a quarter of the sample, confirming observations by Maina, et al. (2016) that respondents within the region are generally reluctant to disclose income levels of their households.

Table 2: Demographic profile of respondents and housing characteristics (n 24)

Demographics		**Housing characteristics**	
Average Household size	5.71 persons	*Walling material*	
Gender of household head		Cement blocks	77%
Male	54%	Bricks	13%
Female	46%	*Floor material*	
University educated	75%	Cement screed	46%
Employed	73%	Ceramic tiles	42%
Average Age of household head	45.79 years	*Roofing material*	
Marital status of household head		Longspan aluminium	79%
Married	85%	Villa tiles	8%
Single	15%	Asbestos	13%
Average Residency	8.5 years	Burglary proof	65%
Tenancy status		External Doors changed	85%
Homeowner	50%	Windows changed	85%

Table 2 also presents data on housing characteristics from the survey. Results reveal that virtually all roofing materials had undergone changes from the original corrugated galvanized sheets. Components were also targets of transformation as 85% of external doors and windows had been changed from the original steel framed glass panel design. The incursion of burglary proofing suggests that changes to doors and windows reflect residents' responses to the mitigation crime, banditry, insurgency and insecurity across many parts of northern Nigeria in the last decade.

4.2 Results of spatial patterns

Spatially, results from the measured survey illustrates an increase of 34% in functional spaces. Results in Table 3 reveal that WCs and bedrooms account for 43% of all spaces within transformed dwellings, with an average of four (4) each per dwelling. Observations during the course of fieldwork revealed that the exclusive use of ensuite toilets/bathrooms by residents was the most desired quality and not necessarily the sizes of combined toilets and bathrooms. This trend reflects changes in the cultural orientation of respondents from a traditional communal way of life to contemporary living standards where privacy levels in terms of personal care has become a top priority (Umbelino, 2017). This is a legacy of western standards associated with higher educational qualifications and standards of living. Residents generally prefer bungalows where all functional spaces including services are accommodated and accessed within enclosed confines of exterior walls, unlike obtains in the original prototype. This is another legacy of British occupation in Nigeria.

Courtyards and sitting rooms were also added to most dwellings, with an average of two (2) each per dwelling, compared to one (1) in the original design. The addition of courtyards was largely because all houses surveyed had fences surrounding entire plots, thus creating an additional courtyard in each transformed dwelling (Figure 2). This finding supports previous observations that fencing entire plots is one of the first signs of transformation in the region (Adedayo, 2012). This had implications on the topological character of transformed dwellings as discussed in succeeding sections.

Table 3: Functional spaces*

House#	**WC**	**Br**	**Ct**	**Vr**	**Sr**	**Kt**	**Os**	**Co**	**St**	**Bt**	**Rm**	**Dr**	**Sd**	**Po**	**Total**
Original	1	2	1	2	1	1	1		1	1					11
1	3	3	1	1	2	1	1	1	1						14
2	9	6	3	1	1	1	1		1		1				24
3	4	4	3			1	1								13
4	5	4	2	1	2	1	1	1	1						18
5	5	4	1	2	2	1	1	2			1	1			20
6	5	5	1	1	1	1	1	1	1						17
7	2	3	2	2	1	1	1		1	1	1				15
8	8	7	1	3	3	1	1	4	1			1	1		31
9	6	5	2	2	2	1	1	3	1			1	1		25
10	1	2	3	1	1	1	1		1	1					12
11	5	5	1	2	2	1	1		1						18
12	4	3	2	2	1	1	1		1	1					16
13	1	2	2	1	1	1	1		1	1				1	12
14	2	3	2	2	2	1	1	1	1						15
15	3	4	2	2	2	1	1		1	1					17
16	1	2	2	1	1	1	1		1	1					11
17	2	5	2	2	1	1	1		1	2					17
18	3	3	2	1		2	1		1						13
19	3	4	2	1	2	1	1		1						15
20	4	3	1	1	1	1	1			1					13
21	3	3	2	1	2	1	1		1						14
22	2	2	2	1	2	1	1		1		1				13
23	3	2	2	2	1	1	1		1						13
24	4	4	2	2	2	1	1								16
25	4	4	2	4	2	1	1		1						19
26	1	2	2	2	1	1	1		1	1					12
Total	**94**	**96**	**50**	**43**	**39**	**28**	**27**	**13**	**23**	**11**	**4**	**3**	**2**	**1**	**434**
Av.^	**4**	**4**	**2**	**2**	**2**	**1**	**1**		**1**						
%	21%	22%	11%	10%	9%	6%	6%	3%	5%	2%	1%	1%	0%	0%	98%

*WC=Water-Closet/bathroom, Br=Bedroom, Ct=Courtyard, Vr=Veranda, Sr=Sitting room, Kt=Kitchen, Os=Outside/root space, Co=Corridor/lobby, St=Store, Bt=Bathroom, Rm=multipurpose room, Dr=Dining room, Sd=Study, Po=Poultry ^Nearest whole number

Spatial transformations were categorised in four groups. These are illustrated in Figure 2. Dwellings were either minimally modified with fences being the only addition (Group 1), or had spaces added to the original prototype (Group 2). Group 3 combined modifications to the original units with isolated stand-alone structures within courtyards while Group 4 comprises of five completely redesigned bungalows.

As earlier described, the first group of spatial transformations, comprising three dwellings (10, 16 & 26) had minimal changes, notably the addition of fences. Group 2 contains modified dwellings by addition of spaces to the original dwelling, the most obvious being sitting rooms (Figure 2). Five of the eight houses in this category contain double sitting rooms (4, 14, 21, 22 & 24) while the other three (2, 18 & 3) contain deep verandas which connect sitting rooms directly to courtyards. The verandas act as living spaces opened on one side which function as family sitting rooms. This trend is again suggestive of a focus on private family lifestyle contained within a bungalow, unlike traditional dwellings that usually comprise separate but proximate units arranged around open courtyards.

Figure 2: Spatial patterns of the original prototype and transformed houses

The largest group (Group 3) contains 10 houses characterised by the addition of self-contained bedrooms with ensuite toilets/bathrooms within stand-alone structures separate from the main dwelling (Figure 2). These typically accommodate grown up male children, locally referred to as "boys' quarters" (BQ in short). This is a legacy of the traditional Hausa culture where older male children sleep separately from females of the household in areas easily accessible to the outside or public spaces of a compound (Muhammad-Oumar, 1997). Hausa culture dominates parts of northern Nigeria especially the northwest where the study area is located. The only exception to this general characteristic occurs in House 13 where a poultry is the sole isolated structure (Figure 2). It is also the only economically related space across the entire sample, suggesting that economic reasons least motivate transformation of public housing in the study area.

Group 4 contains four completely redesigned bungalows. Residents demolished original houses to make way for designs of their choice. Although houses in this group bear no spatial resemblance to any of those within the group or in the other groups, morphological analyses presented in the next section reveal similarities in topological structure with transformed houses from other groups. None of the transformed houses had upper floors. All modifications occurred at ground level in a horizontal rather than vertical manner, supporting previous literature (Shiferaw, 1998).

4.3 Results from morphological analyses

On average, transformed houses were more integrated (H^* 0.72) than the original prototype (H^* 0.52). This observation supports results from previous studies (De Franca, et al., 2019; Reis, 2003). All transformed dwellings contain rings as the original prototype (Figure 3), presenting distributed systems. Distributedness or non-distributedness describes the quality of a system to present a ring or tree configuration respectively (De Franca et. al. 2019). These are usually visualised through JPGs. Distributed systems present systems of rings with alternate routes. Non-distributed systems present tree-like JPGs without rings and offer one possible route for accessing spaces within systems. Three houses (8, 9 and 11) contain double rings and present the most distributed JPGs across the sample. While Houses 8 and 9 are completely redesigned, House 11 is a modification of the original prototype (Figure 2).

Six categories comprising 5 genotypes and a non-genotype emerged from the analyses. These are presented in Table 4.

Table 4: Morphological classification of the original prototype and transformed houses

Genotype	Code	House numbers	%
1	**Vr-Ct-Sr**	Original, 3, 7, 10, 12, 13, 16, 18, 20, 26	34%
2	**Sr-Vr**	4, 11, 14, 22, 23, 24	23%
3	**Co-Sr-Kt**	1, 6, 9	12%
4	**Ct-Ct**	15, 17, 25	12%
5	**Sr-Ct**	5, 19, 21	12%
Non genotype	-------------	2, 8	7%

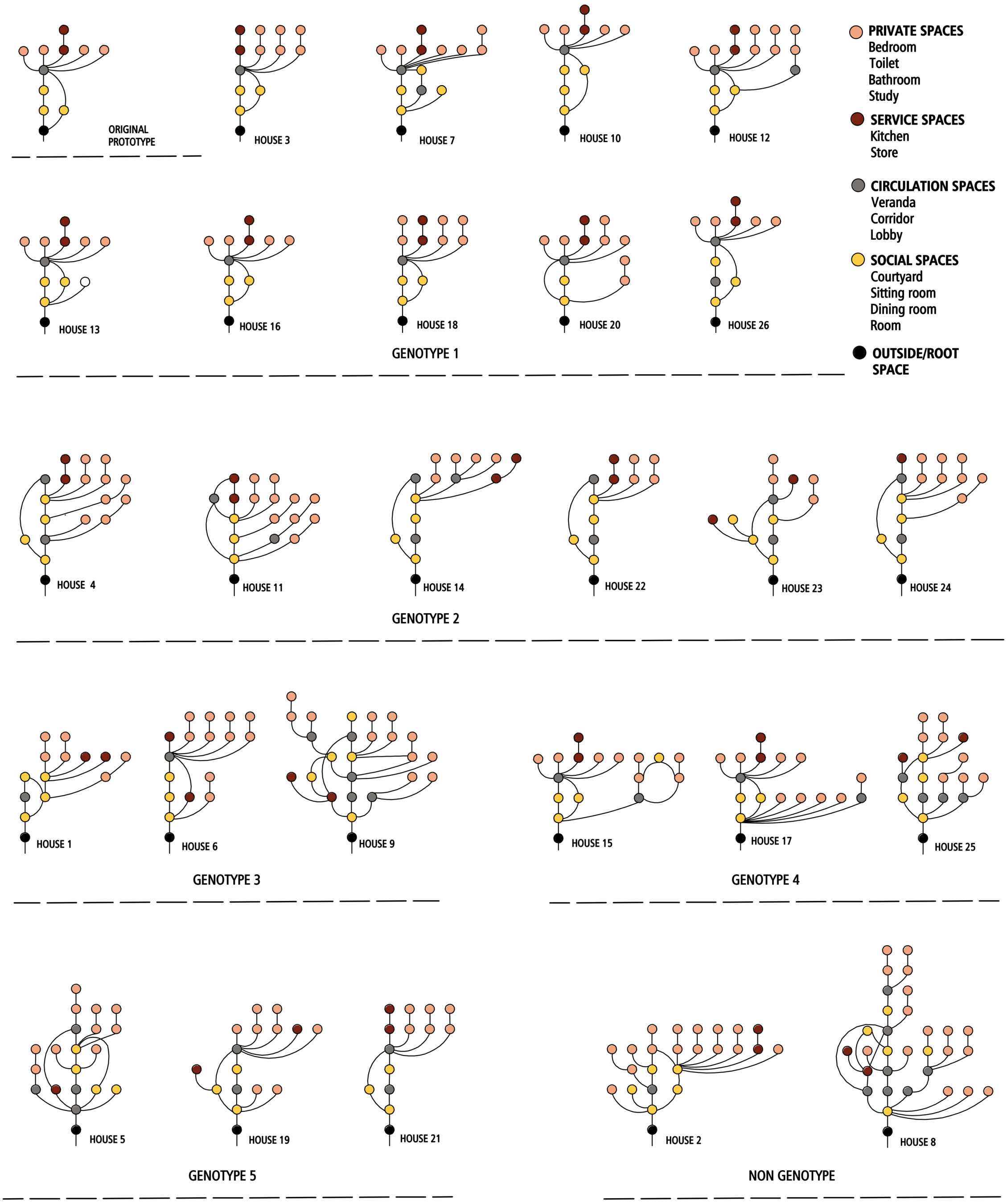

Figure 3: JPGs of the original prototype and transformed houses

Houses in genotype 1 share the same topological characteristics as the original prototype and account for 34% of the entire sample. JPG and convex map analyses reveal that the original unit is five steps deep from the root (Figure 3) with a single ring connecting all social and circulation spaces (courtyards, sitting rooms and verandas) to the outside root node. Houses in genotype 1 thus have the veranda, which is the only circulation space, demarcating and controlling access to private and service spaces from social spaces. Consequently, verandas emerged as the most integrated spaces across all houses in this category (Figure 4). These are followed by courtyards and sitting rooms, thus the code Vr-Ct-Sr (Appendix). Private and service spaces are always the least integrated in this genotype.

The second genotype contains six houses, accounting for 23% of the sample (Table 4). Sitting rooms and verandas emerged as the most integrated spaces within this category (Figure 4). The verandas function as sitting rooms due to their deep shape and direct connection to courtyards. Houses in this category are generally deeper than those in the previous genotype (6 steps from the root node, average mean depth 2.96, see Appendix). The exception to this observation is House 11 which is 5 steps from the root node with two interconnecting rings, supporting the observation that rings mediate depth in relation to increase in integration (De Franca et al., 2019). In contrast to the first genotype where private and service spaces were connected to systems via verandas 3-4 steps deep, social spaces also serve as distribution nodes in the second genotype at shallow depths (Figure 3). Consequently, sitting rooms and verandas emerged as the most integrated spaces (Figure 4), thus the code Sr-Vr (Appendix). Like the first genotype, private and service spaces were segregated.

The third genotype consists of three completely new re-designed houses with the distinct quality of corridors functioning as internal courtyards. These were the most integrated in the systems (Figure 4). JPGs of Houses 6 and 9 reveal that service spaces (kitchens and stores) are located at shallow depths to the exterior, unlike exists in the first two genotypes. In House 1, service spaces are higher in the JPG on the fourth level, a deviation from previous genotypes where kitchens control access to stores. All service spaces in this genotype are directly accessible from social spaces, particularly sitting rooms. This configuration suggests greater integration of services to social spaces.

Genotype 4 also contains three houses (15, 17 and 25) characterised by relatively shallow depths for private and circulation spaces compared to previous genotypes as illustrated by their JPGs in Figure 3. Convex map analyses reveal that courtyards are the most integrated spaces in genotype 4 (Figure 4), thus the code Ct-Ct (Appendix). Ensuite toilets/bathrooms and stores were most segregated. This genotype recorded the highest H^* (0.82) across the sample, confirming that connectivity to courtyards increases integration for dwellings in the region (Maina, 2013) and other parts of Africa (Bessioud & Mazouz, 2017). Recall that courtyards are social spaces where diurnal activities traditionally occur in most parts of northern Nigeria.

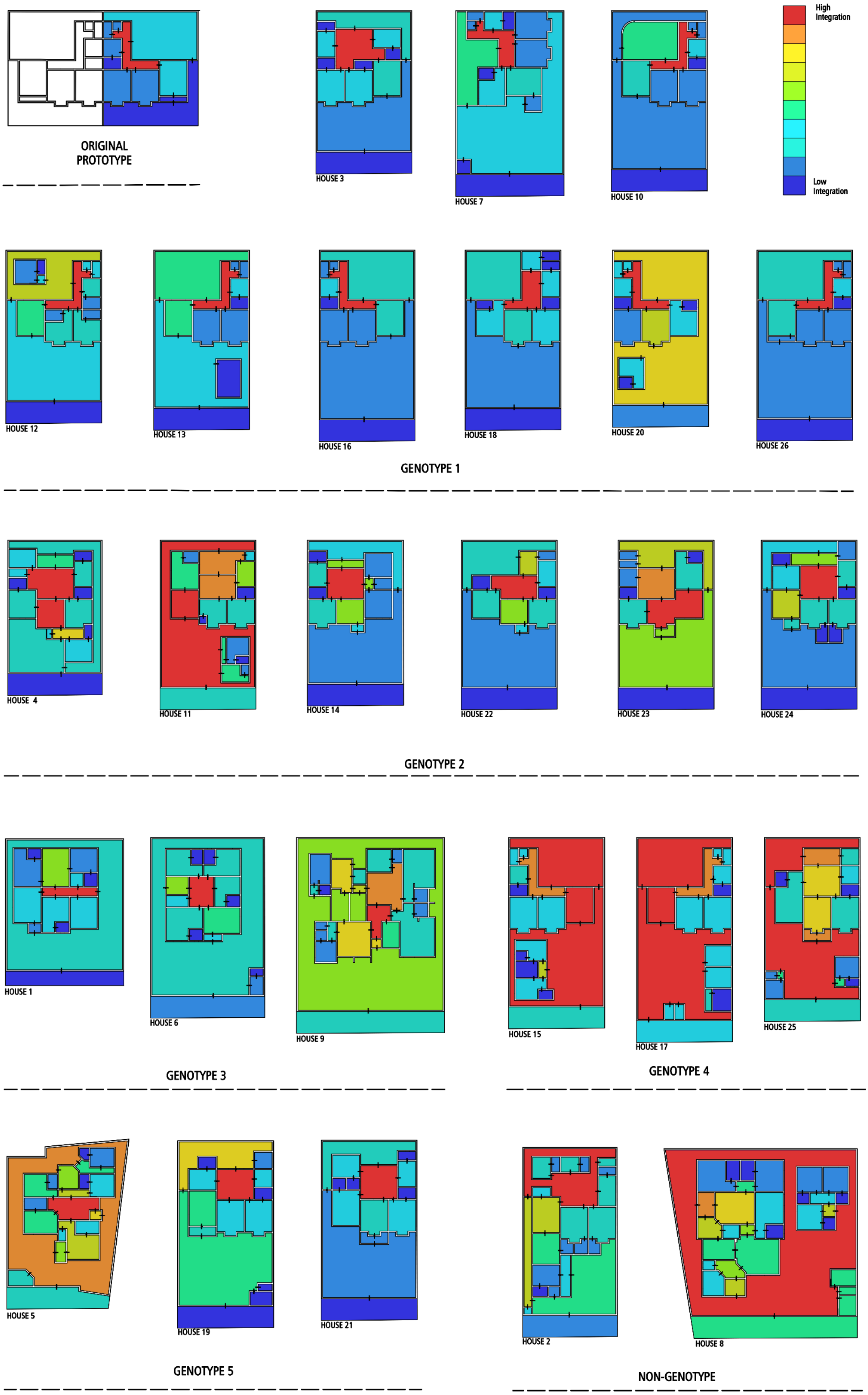

Figure 4: Convex map analyses of the original unit and transformed houses

The last genotype, also containing three houses (5, 19 and 21) has deep tree-like JPGs, House 5 having a larger ring connecting more spaces than the other two houses (Figure 3). Family sitting rooms (the deeper of the two sitting rooms) emerged as the most integrated spaces due to direct links to courtyards, thus the code Sr-Ct (Table 4, Appendix). The family sitting room also links other social spaces to service and private spaces, functioning as the prime living and distribution space centrally located within the houses. Houses 2 and 8 share some characteristics with genotypes 1 and 4 where courtyards were most integrated. Syntactic data from the two houses however deviate from the characteristics of those genotypes in terms H^*, sequencing of IVs, average mean depth as well as number of functional spaces (Appendix). They were thus categorised under the non-genotype category. They contain many spaces (24 and 31 respectively) compared to the original prototype which contains eleven (11). Their JPGs also reveal both shallow and deep configurations (Figure 3) with social and circulation spaces serving as distribution spaces within the houses.

4.4 Results from satisfaction ratings

Results in Table 5 reveal that on average, residents were most satisfied with all spaces in the transformed houses except stores which cumulatively record a mean value below the mid-point value of 2.50. Residents were particularly satisfied with bedrooms, WCs and baths, the last two existing as ensuite toilets and bathrooms within transformed houses. WCs and bedrooms were the most frequently added spaces from transformative efforts of residents (Table 3). These spaces also recorded the lowest standard deviations in Table 5, implying a consistency in satisfaction ratings from respondents across the sample.

Table 5: Satisfaction with spaces

Space	Not available	Very Dissatisfied	Dissatisfied	Satisfied	Very Satisfied	Missing	Mean	Std. Dev.
Bedroom	0	1	2	11	8	4	3.18	0.795
WC	0	0	3	13	4	6	3.05	0.605
Bath	1	0	2	13	5	5	3.00	0.894
Sitting room	0	3	0	14	5	4	2.95	0.899
Veranda	1	0	3	12	4	6	2.90	0.912
Kitchen	0	2	6	11	3	4	2.68	0.839
Corridor	4	1	0	10	5	6	2.55	1.468
Store	1	3	6	9	3	4	2.45	1.057

Genotype 5 emerged as the most satisfactory genotype with a mean value of 3.00 out of 4.00 in Table 6. This genotype is characterised by family sitting rooms directly connected to courtyards as well as other social, service and private spaces. Family sitting rooms in this genotype primarily function as ‘covered interior courtyards’ and the focus of family life in contemporary societies of northern Nigeria. This suggests a modernised variation of family living as these interior integrated spaces within bungalows serve similar roles as open courtyards where diurnal activities traditionally occur in most parts of the region. Family sitting rooms do not replace courtyards in the study context; they are directly connected to them. This finding supports observations that the most integrated space within this context should ideally be directly connected to a courtyard or veranda in houses designed as bungalows or single units (Maina, 2013). Such a design consideration becomes pertinent when open courtyards or verandas are not the most integrated space in a system. More studies are however required to verify this trend for generalisation across the region.

Table 6: Satisfaction based on genotypes

Genotype	1	2	3	4	5	Non genotype
Mean Satisfaction (M)	2.68	2.69	2.97	2.49	3.00	2.89

Genotype 4 was the least satisfactory (M 2.49) followed by genotype 1 (M 2.68). Both contain open-sided verandas and courtyards as the most integrated spaces controlling access and movement into service and private spaces. Results from Table 6 suggest that the open-sided nature of verandas in theses genotypes may have contributed to dissatisfaction rather than the property of control to access and movement. This is because houses in genotype 3 record the second highest satisfaction scores despite having circulation spaces (interior corridors) strongly controlling access and movement to other spaces (Figure 3, Houses 6 and 9). Satisfaction in this instance is associated with enclosed, secure and well-integrated social living spaces with direct links to open courtyards as well as other service and private spaces. Spatial configurations that violate these qualities are likely to foster dissatisfaction in the study context.

5 CONCLUSIONS

This study set out to explore spatial patterns and morphological genotypes as well as to establish the most satisfactory genotypes from user-initiated transformation of public housing units in northern Nigeria. The goal is to inform design of similar schemes in future. Results from an architectural measured survey and Space Syntax analyses of transformed houses reveal that all plots had been completely fenced, creating at least two courtyards within the houses. This reflects the tendency of residents to incorporate traditional forms of daily life within contemporary housing units. Components such as doors and windows as well as roofing materials were replaced in most of the transformed houses. Spatially, ensuite toilets/bathrooms and bedrooms were the most added spaces across the sample, averaging four each per dwelling. This reveals a change from communal traditional lifestyles where basic services such as toilets were shared to a more individualistic and personalised way of life associated with western standards. Economic related spaces were the least added across the sample. Residents of public housing in the study area were least motivated by business and economic factors when modifying their homes. Morphologically, IVs of transformed houses were on average higher than that of the original prototype as transformed houses displayed less rigid control to access. Transformed houses displayed more flexibility in choice of movement compared to the original prototype. The first of five genotypes from syntactic analyses contained the largest proportion of the sample and share the same topological characteristics as the original prototype. This observation offers strong support for the observation that original designs influence transformations. Results from satisfaction ratings however revealed that residents in this category were among the most dissatisfied after those in genotype 4. Well integrated, enclosed and secure social living spaces having direct access to open courtyards and verandas were design features associated with satisfaction in the study context. The study concludes that dissatisfaction is likely to occur if social areas particularly family sitting rooms are not integrated and personal spaces such as bedrooms as well as attached toilets/bathrooms are not segregated within houses. The study recommends that the design of private dwellings especially future public housing prototypes will need to be flexible enough to accommodate an optimum number of four bedrooms, each equipped with an ensuite toilet/bathroom. Designers also need to bear in mind that extensions and additions to prototype dwellings within public housing estates are likely to project out into open courtyards from private, service and circulation spaces notably bedrooms, verandas, kitchens/stores as well as bathrooms/toilets. The implication on urban planning is the gradual reduction of open green spaces within formally designed public estates over time and its long-term effect on climate change within the microcosm of housing and urban neighbourhoods. Adding a WC to each bedroom also has implications on service infrastructure notably water supply and waste disposal. Future schemes will need to factor these within planning proposals to address shortages of water supply and waste disposal within public housing estates in northern Nigeria (Maina et al., 2021). Quantifying the impact and cost of these transformations at neighbourhood and urban levels where their cumulative effects eventually manifests is beyond the scope of the present study. It however presents interesting avenues for future research.

Designs or transformation of future private and public housing in the region will also increasingly incorporate centrally located family living rooms within bungalows. Additionally, plots will likely be completely demarcated by fences. The design of plots will therefore need to specify appropriate fence lines in order to mitigate issues associated with contravention of setbacks when expanding communal infrastructure such as roads, drainage, water supply pipes, telecommunications and sewage lines. This was an emerging problem observed during the fieldwork.

Despite these findings, the study was not devoid of limitations. The sample size and coverage limits generalisation of results although previous studies also report similar sample sizes which range between 15-30 per prototype (De Franca, et al., 2017; Aryani, et al., 2017; Reis, 2003; De Guzman, et al., 2001). The small sample size however presented opportunities to fine tune the mixed methodology employed in the study. Traditional residential satisfaction approaches employing subjective ratings were integrated with objective syntactic measures from Space Syntax analyses in the study area. This sets the stage for further exploration on transformation of dwellings using larger samples and different prototype designs. A laudable strength of Space Syntax analyses is that it is capable of unearthing morphological features useful for inferring common or divergent design features across seemingly different proposals in order to improve design and planning decisions that would have otherwise remained hidden using spatial observations and traditional social surveys alone. For instance, although floor plans of Houses 3 and 18 differ spatially in Figure 2, they have identical morphological configurations based on their JPGs in Figure 3. Likewise, houses in genotypes 4 and 5 contain completely redesigned bungalows and houses modified from the original prototype (Figure 4). Yet floor plans of these houses share remarkably similar syntactic characteristics to be classified together under their respective genotypes (Table 4, Appendix).

Another limitation relates to the subjective nature of satisfaction ratings employed in the study. Satisfaction is contextual and depends on several factors other than spatial configurations derived from floor plans employed in the present study. These include but are not limited to the overall quality of spaces produced, construction methods and material finishes employed within transformed buildings, available amenities, facilities and service infrastructure as well as the social environment of the neighbourhood. The latter is especially pertinent since social networks are essential ingredients to sustainable control and management of major decisions regarding autonomous housing which ultimately foster satisfaction (Turner, 1977). More studies are necessary to explore the effect these variables have on the satisfaction of residents within autonomously owned transformed public housing estates. Future studies will also be required to establish syntactic measures that associate and predict satisfaction within transformed units. Investigating spatial and social networks within estates in the future is also likely to reveal other environmental features that influence transformation at neighbourhood and urban scales.

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APPENDIX

Syntactic values of the original prototype and transformed houses

House No.	K spaces	Av MD	*H**	Sub type	Genotype code	Integration
Original prototype	11	2.16	*0.52*	Vr, Ct, Sr, Kt	**Vr-Ct-Sr**	**Vr** (4.42)> **Ct=Sr** (1.45)> **Kt** (1.33)> Br=Br=Bt=WC (1.11)> Vr=Os (0.88)> St (0.7)
Genotype 1		**2.36**	***0.63***		**Vr-Ct-Sr**	
3	13	2.67	*0.64*	Vr, Ct, Sr		**Vr** (2.60)> **Ct=Sr** (1.30)> Br=Br=Br=Kt (1.14)> Ct (0.87)> WC=WC=WC=WC (0.67)> Os (0.57)
7	15	2.47	*0.68*			**Vr** (2.94)> **Ct** (1.68)> **Sr** (1.47)> Br=Kt (1.24)> Ct (1.18)> Br=Br=Bt=WC (1.12)> Vr (1.07)> WC=St (0.74)> Rm=Os (0.71)
10	12	2.06	*0.6*			**Vr** (3.13)> **Ct** (1.74)> **Sr** (1.57)> Kt (1.21)> Ct (1.12)> Br=Br=WC=Bt (1.04)> Ct (0.98)> St (0.68)> Os (0.65)
12	16	2.73	*0.63*			**Vr** (2.2)> **Ct** (1.65)> **Sr** (1.2)> Kt=Br=Br (1.09)> Ct=Vr=WC=Bt (1.01)> Br=WC=WC=St (0.69)> Os (0.66)> WC (0.51)
13	12	2.17	*0.68*	-		**Vr** (2.61)> **Ct=Sr** (1.57)> Kt=Ct (1.12)> Br=Br=WC=Bt (0.98)> Po=Os=WC (0.65)

House No.	K spaces	Av MD	*H**	Sub type	Genotype code	Integration
16	11	2.01	*0.53*			**Vr** (3.32)> **Ct=Sr** (1.47)> Kt (1.21)> Br=Br=WC=Bt (1.02)> Ct (0.95)> St (0.66)> Os (0.58)
18	13	2.67	*0.64*			**Vr** (2.60)> **Ct=Sr** (1.30)> Br=Br=Br=Kt (1.14)> Ct (0.87)> WC=WC=WC=St (0.67)> Os (0.57)
20	13	2.35	*0.69*			**Vr** (2.27), **Ct** (1.82)> **Sr** (1.65)> Br (1.07)> Kt=Br=WC=Bt (0.96)> Br (0.91)> Os (0.86)> WC (0.65)> WC (0.61)> WC (0.57)
26	12	2.09	*0.59*			**Vr** (3.13)> **Ct** (1.57)> **Sr** (1.42)> Kt (1.21)> Br=Br=WC=Bt=Ct (1.04)> Vr (0.98)> St (0.68)> Os (0.63)
Genotype 2		**2.95**	***0.76***		**Sr-Vr**	
4	18	3.12	*0.81*	Sr-Sr, Co, Vr		**Sr**=Sr (1.70)> Co (1.41)> **Vr** (1.11)> Ct=Ct=Kt=Br=Br (0.98)> Br=WC (0.92)> Br (0.87)> WC (0.83)> WC=WC=St=Os (0.65)> WC (0.61)
11	18	3.04	*0.77*	Sr-Ct, Sr-Vr		**Sr**=Ct (1.54)> Sr=**Vr** (1.40)> Kt (1.11)> Vr (0.98)> Br=Br (0.92)> Br=Br=Os (0.87)> St (0.72)> Br (0.69)> WC=WC (0.63)> WC=WC (0.60)> WC (0.51)
14	15	2.97	*0.69*	Sr, Sr-Co-Vr		**Sr** (1.96)> **Vr**=Sr=Co (1.24)> Br=Kt (1.02)> Vr=Ct (0.91)> Br=Br=WC (0.74)> Ct (0.71)> St=WC (0.65)> Os (0.51)
22	13	2.77	*0.74*	Sr, Vr, Sr		**Sr** (1.82)> **Vr** (1.40)> Sr (1.21)> Ct (1.01)> Br=Br (0.95)> Vr (0.91)> Kt (0.87)> Ct (0.79)> St (0.76)> WC=WC (0.61)> Os (0.53)
23	13	2.73	*0.81*	Sr, Vr, Ct		**Sr** (1.65)> **Vr** (1.52)> Ct (1.30)> Vr (1.21)> Ct (1.14)> Br=Br (0.91)> Kt (0.79)> St=WC (0.73)> Os (0.67)> WC=WC (0.57)
24	16	3.04	*0.76*	Sr, Sr, Vr		**Sr** (1.88)> Sr (1.46)> **Vr** (1.32)> Br=Br=Br=Vr (1.01)> Ct (0.94)> Br (0.88)> Ct (0.82)> Kt (0.78)> WC=WC=WC (0.66)> WC (0.60)> Os (0.57)
Genotype 3		**3.14**	***0.7***		**Co-Sr-Kt**	
1	14	2.77	*0.7*	Co, Sr, Ct, Kt		**Co** (2.31)> **Sr** (1.60)> Ct (1.22)> **Kt**=Sr=Br= (1.10)> St (0.99)> Br=Br (0.90)> Vr (0.77)> Os (0.72)> WC (0.67)> WC=WC (0.59)
6	17	2.96	*0.67*	Co, Kt, Sr, Ct		**Co** (2.25)> **Kt** (1.54)> **Sr** (1.33)> Ct (1.17)> Br=Br=Br=Br (1.13)> Vr=St (1.04)> Br (0.77)> Os (0.73)> WC=WC=WC=WC (0.71)> WC (0.55)
9	25	3.7	*0.74*	Co, Sr, Kt		**Co** (1.58)> **Sr** (1.38)> **Kt** (1.32)> Sr=Vr (1.26)> Co (1.23)> Ct=Dr (1.08)> Ct (1.06)> Sd (0.95)> Br=Br=Br=Co (0.91)> St (0.85)> Vr (0.79)> Os (0.75)> Br=WC=WC=WC=WC=WC (0.66)> Br (0.61)> WC (0.48)
Genotype 4		**3.07**	***0.82***		**Ct-Ct**	
15	17	3.08	*0.85*	Ct, Ct-Sr		**Ct** (1.33)> **Ct**-Sr (1.28)> Vr (1.22)> Vr (1.08)> Kt-Os (0.79)> Br=Br (0.77)> Br=Br=WC=Bt (0.75)> Sr (0.6)> St (0.56)> WC=WC (0.55)
17	17	2.58	*0.78*	Ct, Ct-Sr		**Ct** (1.95)> **Ct**=Sr (1.83)> Vr (1.72)> Vr (1.05)> Kt=Os=Br=Br=WC=Bt

House No.	K spaces	Av MD	*H**	Sub type	Genotype code	Integration
						(0.98)> Br=Br=WC=Bt (0.92)> Br (0.68)> St (0.65)
25	19	3.57	*0.82*	Ct, Ct, Vr, Vr		**Ct** (1.26)> **Ct** (1.22)> Vr (1.18)> Vr (1.14)> Sr (1.10)> Sr (1.07)> Vr=Vr (0.86)> Os (0.79)> St (0.75)> Br=Br (0.74)> Kt (0.71)> Br (0.63)> Br=WC (0.61)> WC=WC (0.54)> WC (0.48)
Genotype 5		**2.87**	***0.73***		**Sr-Ct**	
5	20	3.22	*0.75*	Sr, Ct, Vr		**Sr** (1.67)> **Ct** (1.54)> Vr (1.43)> Sr=Co (1.33)> Kt=Vr (1.20)> Br=Br=Co (0.99)> Os=Rm (0.90)> Br (0.86)> Dr=WC (0.82)> Br (0.70)> WC=WC (0.66)> WC (0.61)> WC (0.53)
19	15	2.7	*0.77*	Sr, Ct, Ct, Sr, Vr		**Sr** (2.14)> **Ct** (1.81)> Ct (1.38)> Sr (1.31)> Vr (1.12)> Br=Br (1.06)> Br=Kt (0.98)> St (0.91)> Br=WC=Os (0.78)> WC=WC (0.67)
21	14	2.7	*0.67*	Sr, Ct, Sr		**Sr** (2.60)> **Ct** (1.39)> Sr (1.30)> Br=Br=Br=Kt (1.16)> Ct (0.95)> Vr (0.90)> WC=WC=WC=WC (0.69)> Os (0.61)
Non genotype					---NA---	
2	24	3.12	*0.69*	Ct, Ct, Br, Ct		Ct (2.16)> Ct (1.62)> Br (1.52)> Ct (1.29)> Sr (1.23)> Br=Br=Br=Br=Br (1.18)> WC (1.13)> Vr (1.04)> Rm (0.96)> WC (0.92)> Os=WC (0.84)> WC (0.81)> WC=WC=WC=WC=WC (0.78)> Br (0.73)> WC (0.56)
8	31	4.17	*0.81*	Ct, Vr, Sr		Ct (1.49)> Vr (1.38)> Sr (1.27)> Vr=Kt (1.15)> Vr (1.12)> Co=Co (1.02)> Sr (0.97)> Br=Br=WC=Os (0.95)> Co (0.94)> Co (0.89)> Co (0.87)> Sr (0.82)> St (0.80)> Br (0.75)> Sd=WC (0.74)> Br=Br (0.71)> Br=Br (0.67)> WC (0.63)> WC (0.59)> WC=WC (0.56)> WC=WC (0.54)

to Superior Technico, pp. 183.1-8.