

Analysis of Organic Architecture

Applications in Tract Housing

Design Technology

Research Question: To what extent would organically-designed tract-housing, specifically the Bolwonginen homes, have advantages, in terms of living space compared to structural material usage over traditional geometrical designs if used for a potential community housing project in the UK?

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TABLE OF CONTENTS

Topic.....	3
Introduction.....	3
Research Question:.....	5
Methodology.....	5
Initial Research.....	7
Geometric Architecture in Tract Housing.....	7
Organic Architecture and Its Features.....	11
Additional Considerations.....	16
Modelling Requirements.....	17
Geometric Model.....	18
Organic Model.....	20
Models.....	24
Geometric Model.....	24
Results.....	25
Organic Model.....	25
Results.....	27
Foundation.....	28
Evaluation.....	29
Conclusion.....	31
Bibliography.....	32

Topic

Advantages of organically-designed housing, specifically the Bolwonginen homes, over traditional geometrical designs in terms of living space compared to structural material usage when used for a potential community housing project in the UK.

Introduction

As our interdependence and the benefits of our harmony with nature becomes increasingly obvious, scientists are looking more into its possible implementation into innovations and designs, primarily through biomimicry (Rinaldi, 1). Alongside developing nature-oriented disciplines, organic architecture has been seeing interest recently. Contrasting many buildings constructed in a rigid and geometric style, organic architecture embraces the curved aesthetics of natural forms and emphasizes the connection of buildings to their environment (Heathcote). It is for these attributes that organic architecture is praised, as by replicating the natural world, the amount of designs that come from the philosophy are incredibly varied yet cohesive and intriguing.

While organic architecture has already been applied on small scales with houses and public structures such as the works of Javier Senosiain (Senosiain) and Frank Lloyd Wright (Elman) as well as on larger scales by architects such as Anton Gaudí (Collins), Zaha Hadid, and Santiago Calatrava (Aung); it has been seldom implemented as an option for mass-produced residential housing, like that seen in suburban areas and worker housing units.



Figure 1, “Casa Orgánica” by architect Javier Senosiain (Caballero).



Figure 2, The cathedral “Sagrada Família” (Collins).

Despite it being only an emerging architectural philosophy, organically-designed and biomimetic buildings have numerous psychological and environmental advantages: they are more pleasing and improve well-being by mimicking and incorporating

features found in nature, if applied well, they provide energy efficiency and environmental sustainability, and can harmoniously integrate into nature (Taylor). I wanted to investigate the possible applications of organic architecture in the designs of tract-housing in suburban environments; specifically those which have recently been constructed in the UK to circumvent the housing crisis (Vize). I will analyze possible advantages compared to more orthodox, cubic designs and whether organic designs would mitigate the issues that suburban housing is often criticized for, such as lack of individuality, low quality, over-reliance on personal vehicles, and lack of public spaces or amenities.

Research Question:

To what extent would organically-designed tract-housing, specifically the Bolwonginen homes, have advantages, in terms of living space compared to structural material usage over traditional geometrical designs if used for a potential community housing project in the UK?

Methodology

Evaluation will be done by comparing the living space of a generic tract house, and an organically-shaped tract house to the structural material usage of both houses. Analysis will be conducted through the creation of digital prototypes which will provide data through measurement tools in CAD software.

Living space is defined as liveable space excluding storage areas like closets and crawlplaces (Law Insider). To reduce the number of factors, the space that would be taken up by furniture will not be considered in determining this variable. Additionally, the additional area of parts such as stairwells will not be considered as they do not add functional living space and could otherwise lead to inaccurate values.

Structural material usage will be determined through analyzing the outer surface area of a building. Although it might be more accurate, the thickness of walls will not be considered, as it would have to take into account many additional variables such as the thickness added by insulation, piping and electrical wires, which would influence values greatly.

Space efficiency between organic architecture and traditional architecture will be compared by creating a coefficient described as:

$$\text{Efficiency coefficient} = \text{Living space}(m^2) / \text{Structural material usage}(m^2)$$

The greater the value for the coefficient, the more living space can be created with less structural materials. As construction is the most significant determinant of cost (Lynch), material usage should be roughly proportional to the costs of creating a house. Therefore the house with the greater “Efficiency coefficient” should be the more suitable option for tract housing as it can provide the greatest living area for the smallest material costs.

Outcomes will be evaluated in relation to additional variables such as the psychological appeal and ability to enhance the social aspects of life in a community housing environment.

Initial Research

Geometric Architecture in Tract Housing

Tract housing is a type of community housing where land is divided into small parcels and many similar if not identical houses are constructed, usually in row-like formations (Gritton). Tract housing has historically been used as a way to create affordable housing (Brown) and is prominent in suburban areas. Due to cost-effectiveness and mass-production, it is generally quite cheap and available. To ensure affordability, tract housing is designed with one or more simple layouts, shared components and space-efficiency (Gritton). Simple, cubic designs allow for efficient planning of space.



Figure 3, An aerial view of housing developments near Markham, Ontario (Duke)

Tightly-packed homes can lead to a sense of community due to regular interactions with neighbors and standardized housing removing wealth and class barriers (“What To Consider When Building An Affordable Housing Community.”). The uniformity and well-established architectural styles of tract housing can also be appealing to buyers who are looking for predictable, standard homes (Gritton).

However, tract housing is not without issues. It suffers from a lack of distinct style, especially with “cookie cutter” construction leading to buildings that all look very similar to one another (Keskeys). Attempts to create variety through using different materials and colors often leads to a lack of cohesion; meaning that most suburbs end up as rows of similarly-colored and shaped houses, creating a monotonous living space (Keskeys). Excessive ownership and use of private vehicles is another problem affecting suburban areas that threatens environmental sustainability (Lindberg, 2). Suburban areas also struggle with inadequate public spaces, partly due to accommodation for cars such as large roads taking up a significant amount of space in suburban areas where homes are placed close together to reduce land usage. These issues also reflect in consumer attitudes towards tract houses. In the UK in 2012, many civilians were against buying newly-built homes due to preferring older ones for their greater space and better quality; despite the housing-crisis at the time (Graef). This same sentiment is still present nowadays, with continued distrust in housebuilders despite the soaring housing prices (Dempsey).

Community housing as a whole has a large impact on the economic and social well-being of a society. Therefore it is important that it is not burdened by negative factors like low quality. Community housing has numerous benefits, like improved

productivity which can result in greater GDP for a country (CHF BC). These issues tend to be quite widespread. For instance, the housing crisis in Canada, suffers from a lack of affordable and suitable housing of decent quality and a general disdain towards tract housing in countries also seen in the United States (DSCENE) and the UK (Collins).

However, there has been a recent surge in the amount of high-quality tract homes in the UK that are ignored as lower quality homes are often highlighted in media, resulting in a negative perception towards tract housing (Dempsey). Monotonous and standardized designs also lead to the negativity towards tract housing, with the long rows of similar or identical houses being likened to a “sinister paradise” (The Mind Circle). These negative connotations can make tract housing undesirable.

However, avoiding it is difficult, due the phenomenon of urban sprawl, where compact cities spread out to larger areas as they grow due to the cheap rural land and driving costs making it less costly to live in proximity to a city rather than within it. Tract housing is often the answer for the housing demand of urban sprawl, resulting in long stretches of houses with little to no public areas or amenities such as parks or community centres which can restrict social interaction and well-being for those living in the area (Yale University). Distance from city centres, where most people living in tract houses work, makes them dependent on private vehicles, resulting in large CO2 emissions and traffic congestion (Rafferty). While policies such as increasing fuel costs to dissuade personal vehicle use can mitigate the negative effects of urban sprawl, city design is a key factor in encouraging people to behave in beneficial ways. Zoning laws, which are used to determine what buildings and infrastructure should be built in certain areas, are also a contributor to urban

sprawl (Rafferty). Designating certain areas for residential housing and others for industrial use for example, creates segregated cities and increases reliance on private transportation, such as for getting to one's workplace or accessing amenities such as stores or restaurants. Improved planning could allow for on-site facilities such as libraries, child-care facilities and community centers which would also create jobs for those living there, leading to developmental growth of the area (DSCENE).



Figure 4, The Nad Al Sheba 3 neighborhood in the UAE (The Mind Circle).

With the establishment of the Building Better, Building Beautiful Commission in the UK, there has been a push to create organically designed buildings with a better public perception as modern tract homes are generally disliked compared to older Victorian and Georgian buildings (Vize). Even with the new commission, there hasn't been significant change which could help alleviate the current biggest problems of tract housing (Vize). One reason for this is maintaining low costs. While it is possible to design community housing sites with various amenities, open spaces, and varied, high-quality houses, it is often too expensive compared to what tract housing aims to provide (Levelle).

Organic Architecture and Its Features

Organic architecture, as opposed to the traditional, geometric architectural styles used to make tract housing, is a relatively new school of design with many bold and unorthodox buildings to its name. Organic architecture is not limited by specific techniques, leading its buildings to be very distinct and varied. While organic architecture is more generally labelled as a school of thought where buildings are designed to be cohesive with their natural context, and integrate into nature aesthetically and functionally (Graff), this essay will focus particularly on some of the specific features of organic architecture. The primary emphasis will be on "organically-shaped" architecture, where buildings have forms and designs based on shapes seen in nature.



Figure 5 Ken Kellogg's "Doolittle House" in Joshua Tree, California showcases the natural shapes and features that will be the focus of this essay (Heathcote).



Figure 6 “Fallingwater” by Frank Lloyd Wright is a famous example of organic architecture yet it primarily has geometric shapes. (Heathcote).

Many works that fit into the approach of organic architecture also feature aspects such as biomimetic or biomorphic design and an emphasis of sustainability and harmony with the environment the building is situated in (Ruthe). Architect Frank Lloyd Wright states that in organic architecture “Form and function are one”, highlighting the importance of incorporating organic designs into their environment and ensuring they satisfy the innate needs of humans and reinforce our connection to nature (casaorganica.org). While not the primary focus of this analysis, the possible benefits of such characteristics will be evaluated as well.

Its emphasis on function and harmony, as well as the unique designs emerging from the approach could be a suitable candidate to solve many of the problems that are present in traditional tract housing.

Natural, rounded shapes and flowing curves that are a prominent feature of organic architecture help create pioneering and memorable designs (Ruthe). Organic forms also have positive psychological and therapeutic effects (Purohit). These effects are enhanced by works that specifically take into account our roots in nature, such as the works of Javier Senosiain, which often resemble caves or burrows in their shapes (casaorganica.org).



Figure 7, The interior hallways of Senosiain's Casa Orgánica, which are buried underground (Caballero).

Organic designs also tend to be more sustainable and friendly to the environment. As they work in tandem with the natural environment, instead of against it, they are

often more efficient and less destructive towards natural ecosystems. For example, Javier Senosiain's "Casa Orgánica" is covered in a 25-centimetre layer of soil that acts as an insulator; keeping the interior warm during the winter and keeping it cool in the summer. The soil layer additionally supports grass, meaning additional area is not taken up for the yard, as it is directly above the house. Organic architecture often uses natural and local materials, to form congruence with the environment it's situated in (Graff). This reduces the ecological footprint left by construction (Purohit). It also usually features open, untraditional floor plans in order to maintain simplicity (Graff). More open, and less restricted floor plans, while not applied in any current projects, has the possibility of being an intuitive way to make the most of the limited space of tract housing projects.

Despite various advantages over geometric architectural designs, organic architecture has some difficulties that make it less prevalent than it would be otherwise. Firstly, organic architecture is generally more complicated and difficult to construct than normal geometric designs, due to incorporating natural materials and flowing shapes. As organic architecture often tries to conform to its surroundings, the widespread use of standardized houses, which is one of the main factors that make tract housing so cheap, is limited (Purohit). Both of these factors usually result in organically-designed buildings being more expensive than conventional counterparts. Furthermore, organic architecture is still a very new and unique field of architecture, and its unfamiliarity might discourage buyers looking for predictable homes. However, uniqueness could also be a benefit, with bold, interesting designs attracting more people. Due to the differing from existing houses, organic designs

could also lead to greater resale values, which current tract housing struggles as homes are often difficult to sell for a good return (Gritton).

Additional Considerations

There are several studies of how community housing in the UK can be modified to meet environmental and social well-being needs, such as the analysis of a new housing project in Derwenthorpe in York (Quilgars, 1) and reports by the Building Better, Building Beautiful Commission (Frank). They can be used to determine what an organically-designed tract housing project in the UK would need to fulfill.



Figure 8, A network of pedestrian and cycle routes cross Derwenthorpe, allowing easy access between neighbourhoods and into the centre of York (RIBA).

In his research report “*Cost and Value*” of several new building projects in the UK, Knight Frank determines several traits about the relationship between costs and revenue of community housing. He highlights that more expensive, higher-quality

houses might actually be more desirable, as buyers are often willing to pay a greater premium, offsetting cost premium (Frank, 13). Sustainable development and long-term considerations are shown to be of more importance than is generally considered, as planning for long-term growth in the design of a community can add value to all stakeholders. Designing communities to be more independent, rather than tied to a large city can bolster the local economy and lead to more beneficial, albeit slower “good growth” rather than urban sprawl. Having local job opportunities also provides amenities to residents and encourages sustainable travel (Frank, 47).

According to the Royal institute of British Architecture, the most important considerations when creating a living area are a suitable place, a choice of homes, integration of nature, sustainability and uniqueness (RIBA, 3). While some aspects such as a variety of homes to choose from are inevitably limited due to the nature of tract housing, these other aspects all play significant roles in how viable a different housing design can be.

Modelling Requirements

The average living space for non-apartment homes in the UK is around 94m² (GOV.UK), although fully separate homes intended for families tend to be on the larger end of the range. For simplicity, it can be assumed that a tract-house should have around 100m² of usable living space not accounting for furniture, in order to be desirable for buyers.

Geometric Model

The geometrically shaped model will be based off of a traditional, Georgian-style home with a living space as it is similar to the designs of many existing tract homes in the UK. Homes similar to those from more praised neighborhoods such as Derwenthrope weren't chosen as they tend to be more luxurious and larger.



Figure 9, A picture of the chosen design. It has several possible aesthetic variations (Houseplansdirect).

The chosen home has 3 floors and a total living space of 118m² and a relatively generic design (Houseplansdirect). The floor plans for the building are publicly available and they will be used to guide modelling.

The 3D model will be based on the same measurements as these plans so that the housing scale and shape is consistent with the real-world example. Figure 10 shows the plans of the first floor, figure 11 the second floor, and figure 12 the roof floor. A surface model will be constructed, as the living space is already provided.

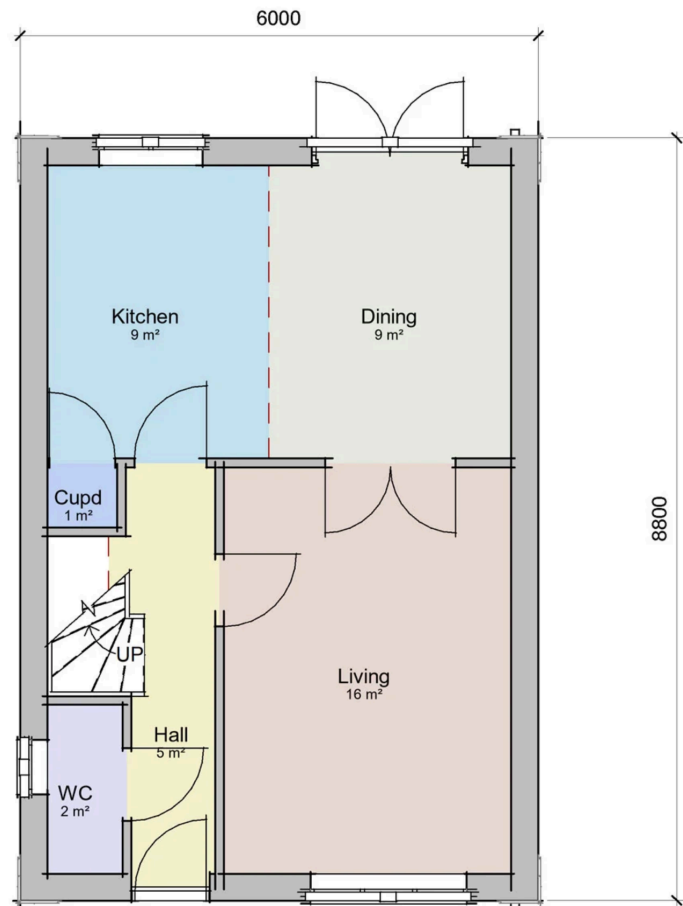


Figure 10

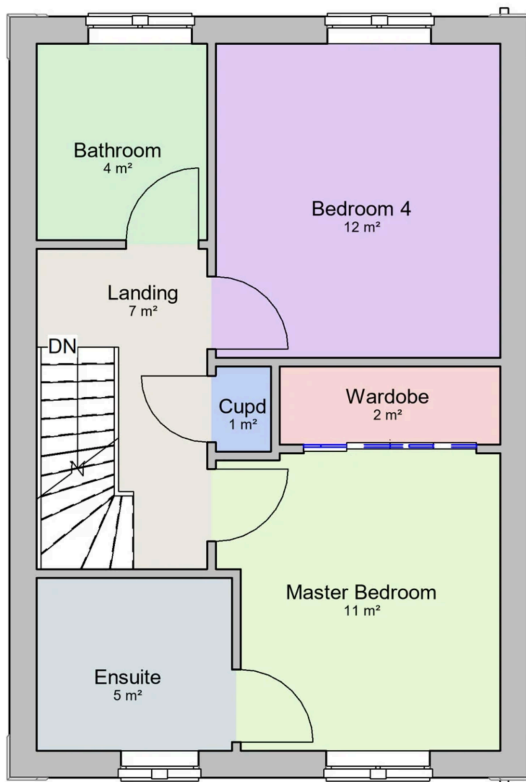


Figure 11

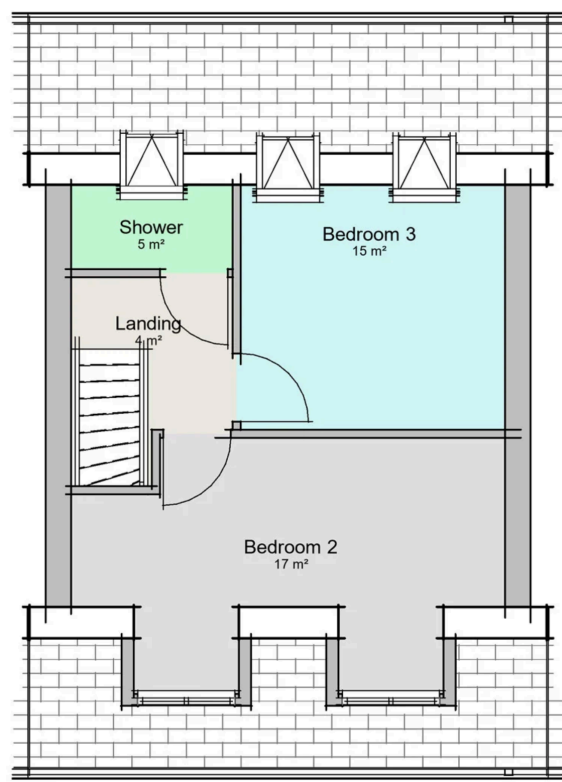


Figure 12

Organic Model

The organic model will be based on the “Bolwoningen” which is a housing unit in the town of Den Bosch in the Netherlands, consisting of 50 spherical houses built in 1984 and designed by architect and designer Dries Kreijkamp (Merin). These houses are suitable for the analysis as they are one of the few attempts of integrating organic architecture into community housing.



Figure 13 The “Bolwoningen” houses (Merin).

The houses were designed for mass-manufacture, being made of a few large parts. The spherical design was inspired by the prevalence of spheres in nature, with Kreijkamp stating “We live on a sphere, we are born out of a sphere... why not live in a sphere?” (Merin). The unique designs of these houses are advantageous as they are extremely lightweight, with the hollow exterior weighing only 1250 kilograms (Merin). This means that the parts could be easily manufactured off-site and

transported. Additionally the houses, thanks to their small size, unique shape, and large windows providing natural light, are extremely energy efficient (Nederlands Instituut voor Beeld & Geluid, 2019). Kreijkamp also had future plans such as connecting the separate spheres or adding attachments to improve upon the design which never reached fruition.



Figure 14 “Bolwoningen” under construction. The sphere is made from fiberglass instead of traditional materials like concrete (Merin).

The houses are quite small, with the three floors totaling to only 55m² and are intended as a living space for individuals or couples without kids (Dogan). The first floor has a small storage compartment and a staircase. The second floor has the bedroom and the lavatory and shower. The third, which is the largest floor, contains the living room and kitchen.

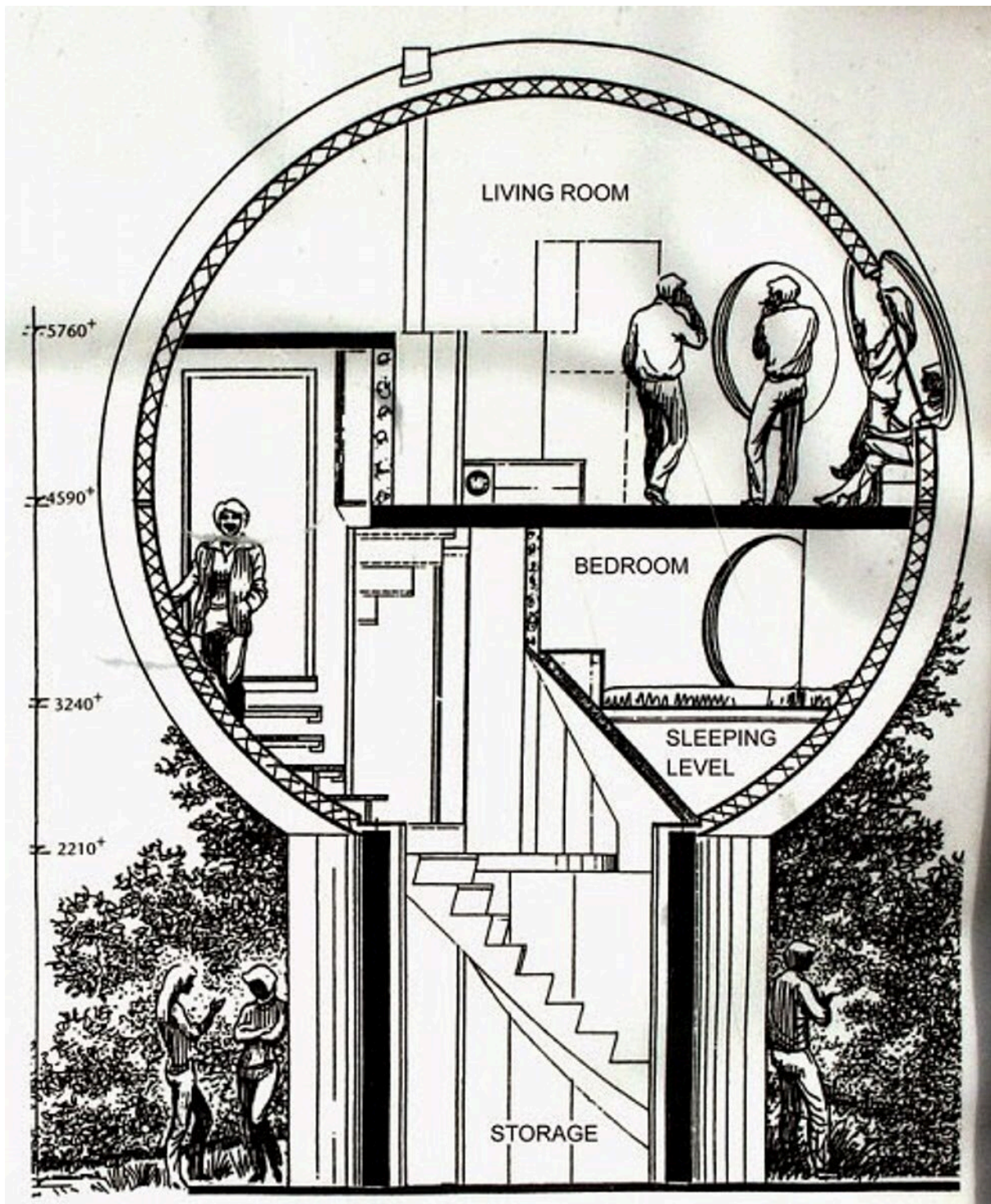


Figure 15, A side-view plan of the Bolwoningen house (Dogan).

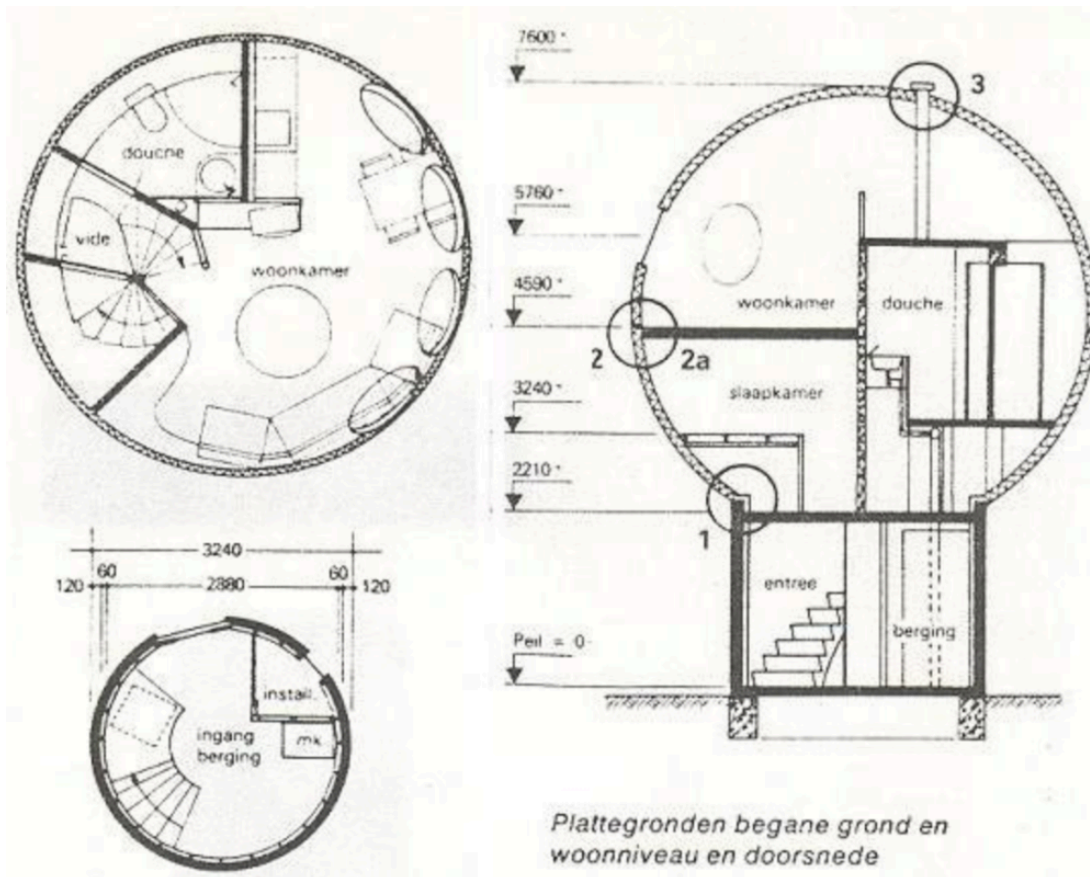


Figure 16, A side-view and top-view plan of the Bolwoningen house (Greyscale).

The sphere has a diameter of 5.5 meters and the cylindrical section is about 2.2 meters tall (Merin). The size is far smaller than what is normal for British homes, and to account for this a scaled up model will be used. Initially, a one to one model will be used with a modelled floor plan to find living space directly from the model. Then it will be scaled up so that the living space of the model is close to that of the geometric model at around 120m². The model is scaled up to prevent any errors that come from the possible disproportionality of living space and surface area.

Models

Both chosen designs were recreated in *Autodesk Fusion 360*, according to real measurements from plans of the homes. Unavailable measurements were recreated as accurately as possible to the source material. Data was then collected by examining the surface area of the exterior and the living space.

Geometric Model

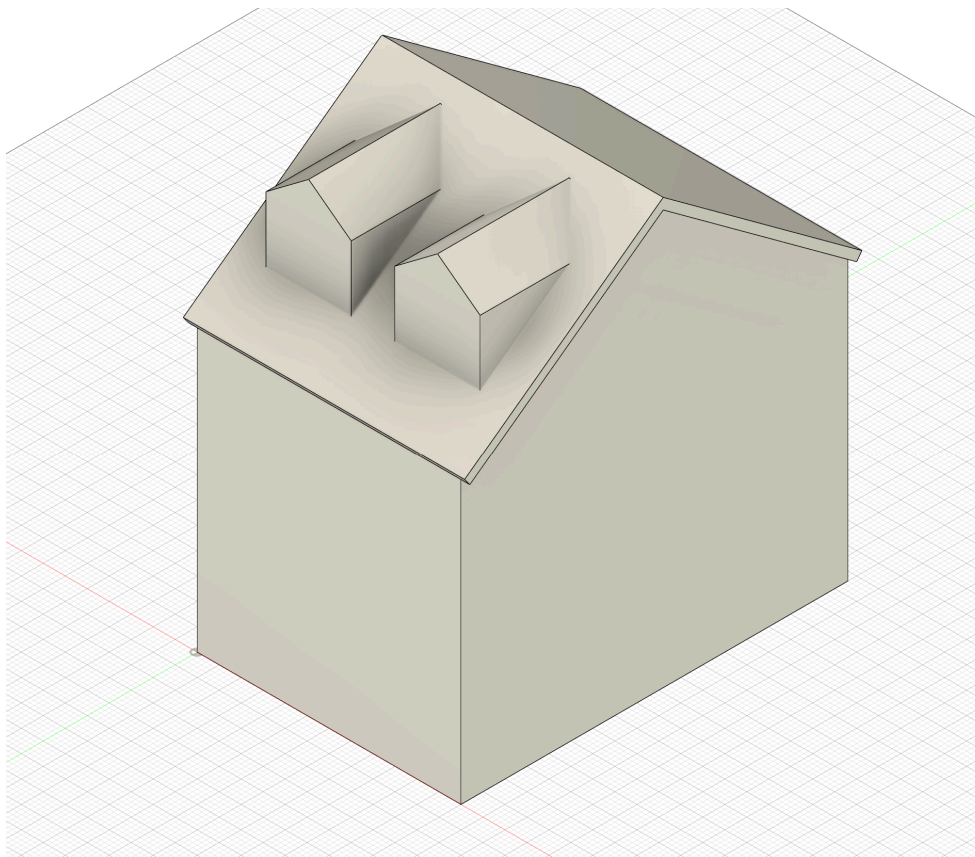


Figure 17, An image of the geometric house model.

The model is 6 meters wide and 8.8 meters long. The ridge is 9.62 meters tall. The living space was not calculated as it is already available in the plans which the model was made according to.

Results

The data was collected using the measurement tool in *Autodesk Fusion 360*, in millimetres squared and then converted to meters squared by dividing the value by 10^6 and then rounded to 3 significant figures. The data for living space was already available and was not processed. The coefficient is calculated as:

$$\text{Efficiency coefficient} = \text{Living space}(m^2) / \text{Structural material usage}(m^2)$$

Where the used values have already been processed to 3 significant figures.

Living Space	Total Surface Area	Efficiency Coefficient
118m ²	332m ²	0.355

Organic Model

For the organic model, two separate models were made: a to-scale version, and an upscaled version. Necessary values were calculated for both in order to highlight any differences that come from translating the Bolwoningen house model to a larger scale. The internal floors were also constructed, due to the need to scale the house. A cross section of the design is shown to highlight the floor plan.

This model incorporates the attachment on the ground floor to the side of the cylindrical base, which is not seen in much of the media related to the creation of the building (Nederlands Instituut voor Beeld & Geluid, 2023) , but is visible in recent images of the house (Merin).

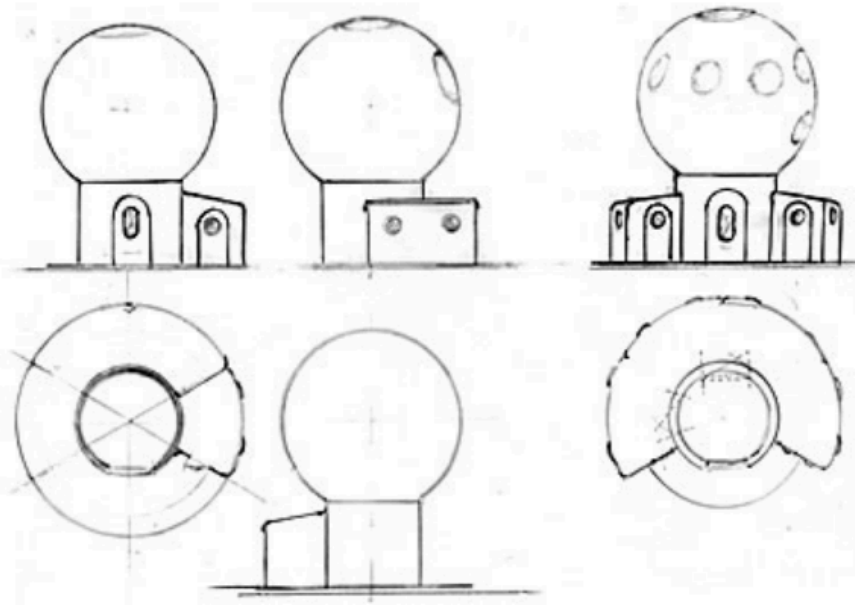


Figure 18, An image of the Bolwoningen showing the attachments (Merin). The actual houses only have one attachment.

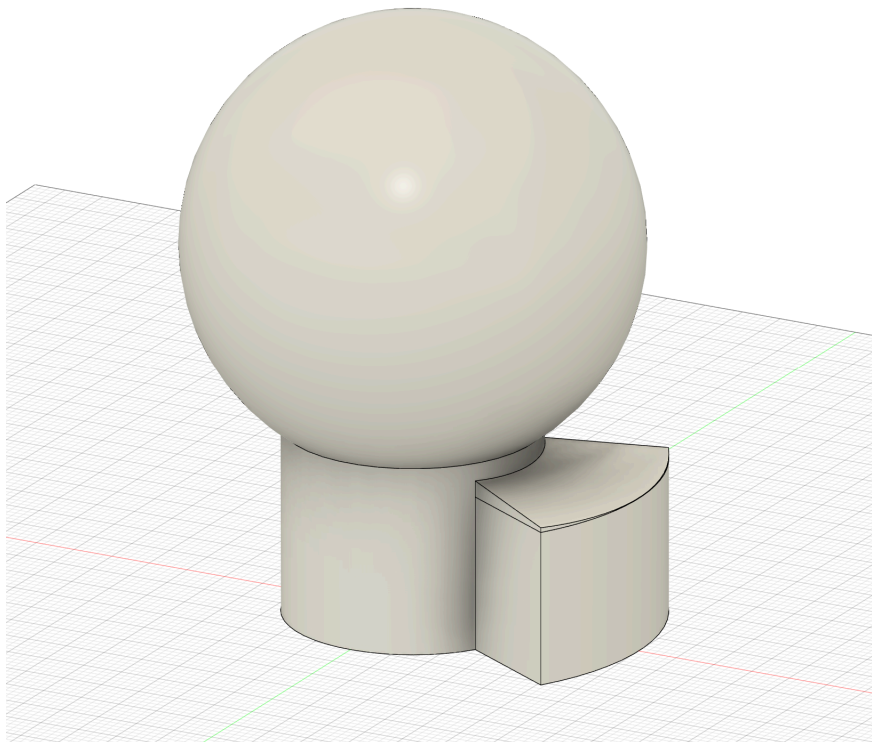


Figure 19, An image of the organic house model.

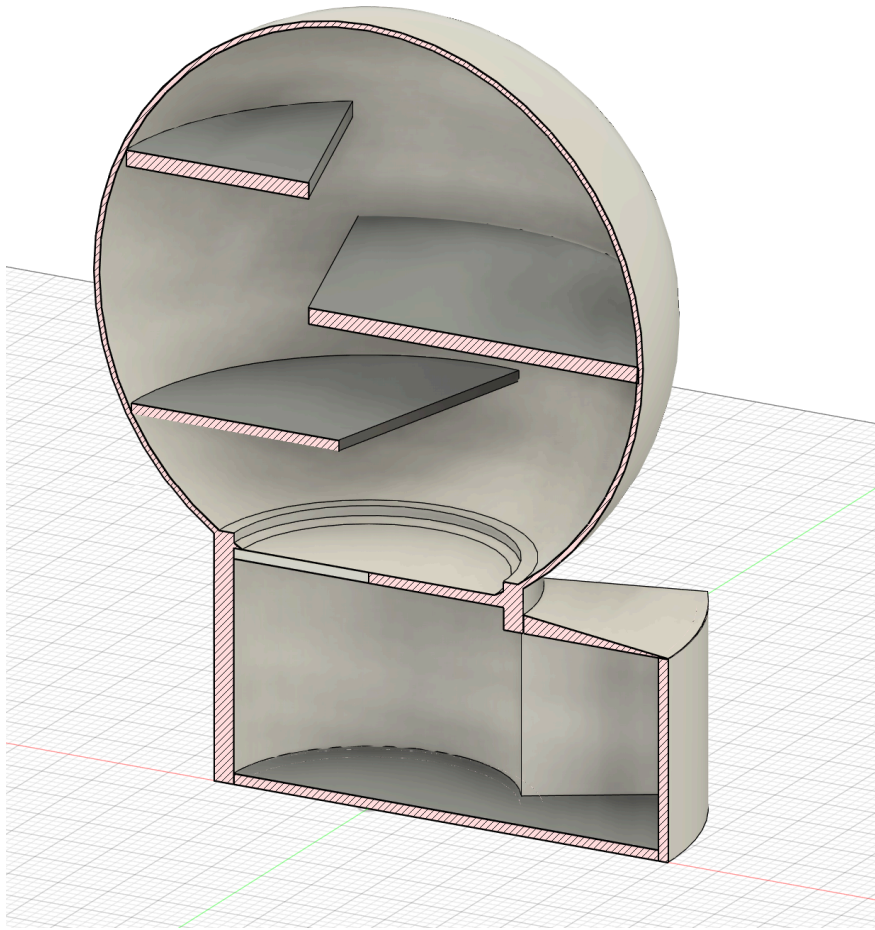


Figure 20, A cross-section of the organic house model.

Results

Model	Living Space	Total Surface Area	Efficiency Coefficient
To-Scale Model	43.1m ²	119m ²	0.362
Hypothetical To-Scale Model	55.0m ²	119m ²	0.462

Model Scaled by Factor of 1.65	117m ²	332m ²	0.352
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A hypothetical to-scale model was used due to the discrepancy between the living space of the digital model and the actual living space of the Bolwoningen buildings. The hypothetical to-scale model uses the reported 55m² (Dogan) and the total surface area measured from the model itself as no such measurements exist for the real-life counterpart.

Foundation

The foundation of a building also has an effect on its material usage and is thus important to consider. Factors that affect foundation include the load the structure applies on the ground, the ground conditions, foundations of adjacent structures and environmental conditions such as soil freezing during winter (BDS Architecture). Assuming all other factors are the same, the weight per area would be the only determinant of the foundation depth. The Bolwoningen would likely be advantageous here thanks to its very lightweight design.

The Rankine's formula can be used to calculate the minimum depth of the foundation required for different types of soil (Bala). From this we can make an estimate for the material used in the foundation.

Rankine's Formula for Hard Clay	$Df = \frac{P}{\gamma(1-\sin\phi/1+\sin\phi)^2}$
Depth (meters)	$Df = 2.09 \text{ m}$

Bearing capacity of the soil (KN/m ²)	$P = 451 \text{KN/m}^2 = 45551 \text{Kg/m}^3$
Density of Soil (Kg/m ³)	$\gamma = 1600 \text{Kg/m}^3$
Angle of Repose (Degrees)	$\phi = 35^\circ$

The values were obtained from the Civil Planets article (Bala).

Category	Bolwoningen (Scaled)	Geometric House
Foundation Area	25.0m ²	52.8m ²
Minimum Foundation Depth	2.09m	2.09m
Minimum Foundation Volume	52.25m ³	110.352m ³

Due to its smaller base, the Bolwoningen has a much smaller minimum foundation volume. As the building is very light, the foundation will likely not need to be increased much to accommodate for load.

Evaluation

The percentage difference between the efficiency coefficients of two models can be calculated using the equation for “Efficiency Advantage”, which is:

$$\text{Efficiency Advantage \%} = \frac{\text{Greater Efficiency Coefficient} - \text{Lesser Efficiency Coefficient}}{\text{Lesser Efficiency Coefficient}} * 100\%$$

Overall, it seems that there is not much difference in terms of living space to the usage of structural materials when it comes to the organically-shaped Bolwoningen compared to the geometrically-shaped house. This can be determined as the difference between the coefficients is only 0.007.

	Bolwoningen	Geometric Model
Efficiency Coefficient	0.362	0.355
Percentage Efficiency Advantage	1.93%	Disadvantaged

However, if the hypothetical organic model where the interior living space is far larger is more accurate, then it would indicate that the Bolwoningen is far more efficient, with a percentage efficiency advantage of about 30%.

	Bolwoningen (Hypothetical)	Geometric Model
Efficiency Coefficient	0.462	0.355
Percentage Efficiency Advantage	30.1%	Disadvantaged

For consistency, the focus will remain on the normal to-scale model and the upscaled model, which both only use measurements from the digital models.

The upscaled model has a slightly lower coefficient than the to-scale model. This coefficient is also extremely close to that of the geometric model, with only a 0.003 difference between the two values. The percentage efficiency advantage of the geometric model is very minor.

	Bolwoningen (Scaled)	Geometric Model
Efficiency Coefficient	0.352	0.355
Percentage Efficiency Advantage	Disadvantaged	0.822%

Conclusion

This analysis shows that the Bolwoningen house, which uses organic architecture, does not differ much in terms of material usage and living space compared to a traditional geometric tract house. Additional factors such as the ease of construction of the Bolwoningen, could result in reduced cost compared to the geometric house. The cheap cost could allow for the implementation of other organic architecture principles, providing unique benefits. More general statements cannot be made about organic architecture due to the limits of the study's scope.

An extension of this study would use more organic models compared with more traditional tract houses. The additional data from the extension would be used to determine the possible applications of organically-shaped architecture as a whole in tract housing, rather than just one specific design. Another extension could also include other elements that might add up to the cost, rather than just considering the material usage.

It is vital to consider that the design of a house is not the only factor that goes into community housing. The location, amenities and infrastructure, and social and environmental factors all need to be considered to create a successful community.

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