The Modular Back-to-Back House – An Interactive Generative Methodology for the Design of a Lifetime Home

Des Fagan[1]
[1] Head of Architecture, Lancaster University, d.fagan@lancaster.ac.uk

ABSTRACT

The research proposes the building of half a house akin to historic 'back-to-back' housing, with the remaining 'half' built over the remaining lifetime of the owner, providing versatile and adaptable room and spaces for the life changes of the owner. The method is based on a unique Autodesk Generative Design definition providing a multi-objective design generation algorithm for creating design iterations for the unbuilt future 'half'. Each homeowner is able to then navigate the thousands of design options generated to evaluate the potential cost of changes to the fabric (linked to the SPONS cost guide) of the house based on their individual lifetime changes; marriage, children, illness, dementia etc., to improve forward financial planning. The work evaluates the effectiveness of the algorithm output through a series of comparisons with established 'lifetime home' case studies.

Keywords: generative, housing, modular, lifetime, planning, automated, algorithm, costing, house

1 INTRODUCTION

The UK population is growing older– now, almost 20 million households are over the 55-year bracket, and those aged 85 and over are predicted to double in the next 20 years. In parallel with an ageing population, housing affordability has led to a growing crisis for first-time buyers, with those in full-time employment typically spending 7.8 times their workplace annual earnings purchasing a home [1]. There are 1.6 million renters who are able to buy but are unable at present due to the prohibitive cost of large housing deposits [2]. As a result, levels of homeownership have fallen in England from 71% in 2001 to around 63% today. This has particularly affected young people: in 2001, 55% of 25-34-year olds were homeowners in the UK. That figure now stands at 35%, and for the following age bracket (35-44), there has been a reduction in homeownership rates from 73% to 61% [3].

The desire to live affordably and inter-generationally needs to be met by appropriate housing options. Choice implies addressing crucial barriers: inadequate space and insufficient opportunities were named in a survey of 2,000 adults as one of the most significant barriers to intergenerational living. Additional issues encompassed uncertainty about future health and employment status and changes to family unit sizes [4]. This research proposes the building of 'half a house', akin to one half of traditional back-to-back housing, to address these problems. The unbuilt 'half' can then be designed through generative optioning of layouts to explore potential costs with a view to forward financial planning.

2 RELATED WORK

Several projects have proposed methods to provide mass-customised housing based on generative systems, focusing predominantly on shape grammar and computational design. Duarte (2004) developed shape grammar systems for Alvaro Siza's Quinta da Malagueira housing estate. Bergin (2009) authored the Housing Agency System, which proposed a fully integrated system for mass-customised housing. More recently, Wang (2017), Griz (2018), Ostrowska-Wawryniuk (2018), Bianconi (2019), Laignel (2020), Wang (2020) have detailed iteratively advanced systems of computer-generated modular housing layouts using software including Python, Grasshopper and Dynamo.

Wider research completed on multi-criteria optimisation of design for building layouts Guo (2017) explores a multi-agent evolutionary optimisation process to define housing layouts using parametric modelling. A recent article by Japanese housing company Daiwa (2019) outlined their current work in Revit Generative Design, which uses multi-objective methods to optimise building plans, sections and materials on small parcels of land [4]. However, none have investigated the automation of housing design considering lifetime homes. In the context of this gap of knowledge, this research proposes a new method to provide for forwarding financial planning for homeowners.

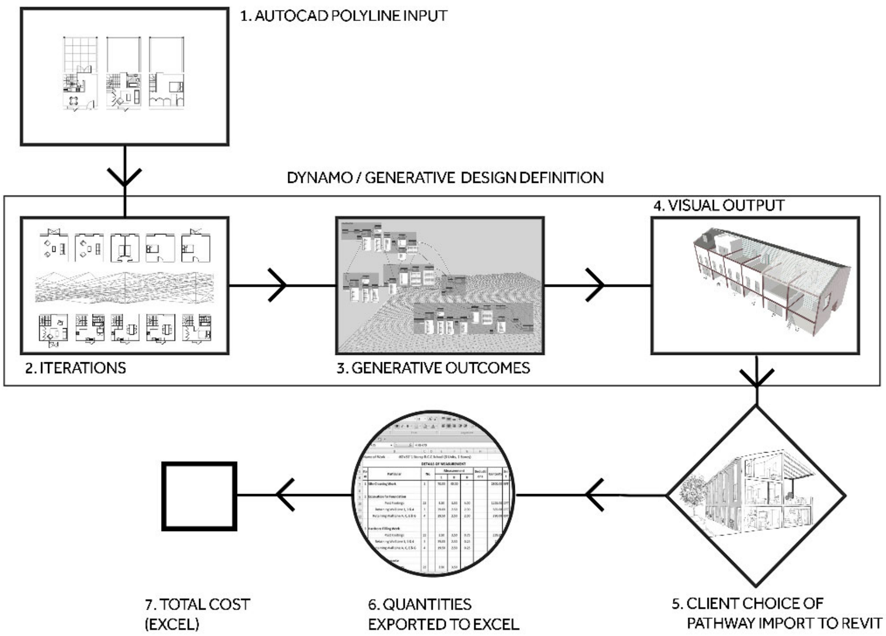

Figure 1: Generative design framework overview in Revit and Dynamo

3 RESEARCH METHODOLOGY

To evaluate the methodology, the project considered the design of a UK street in Holbeck, Leeds adjacent to existing streets of back-to-back housing. The method proposed the contextual imitation of the existing structure and tectonic of the back-to-back streets, constructing just one' half', with the other left 'open' and unbuilt to provide for future lifetime changes or intergenerational living through financial investment. The advantage of this method is that homeowners need to raise a much smaller initial deposit and mortgage. The additional land allows space for expansion, and the generative approach can help determine the visual, spatial and financial implication of future lifestyle changes.

This approach is described in Figure 2, where the 'green' future phase indicates how a homeowner might choose to build on the existing 'base build' to provide a larger living room, two additional bedrooms and a roof terrace. The method allows the user to index contemporary and projected financial costs against quantities for any iterative layout change through the generative software and cost databases.

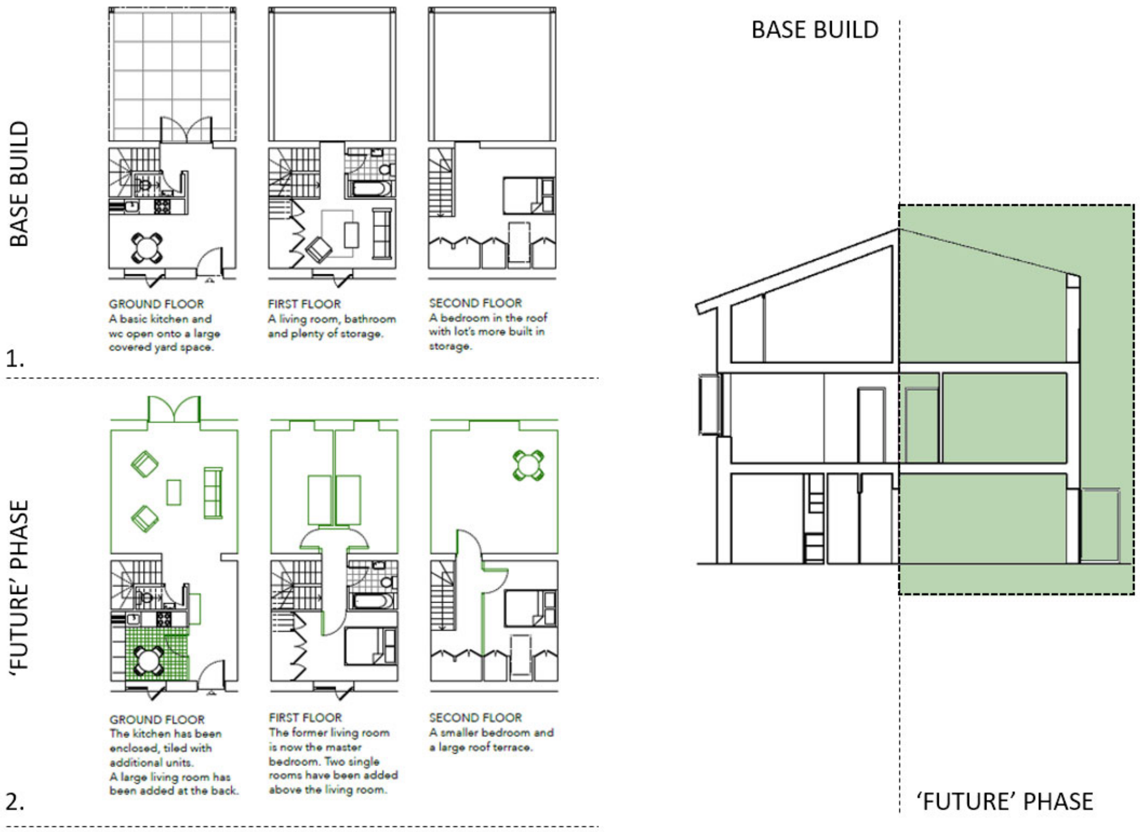

Figure 2: Base build and future build indicated in green

3.1 Dynamo Integration

The project utilises Autodesk's Dynamo and Generative Design integration with Revit. Dynamo was chosen over Rhino's Grasshopper due to its improved integration of complete building systems through Autodesk's comprehensive Building Information Model (BIM) system. This allowed for a detailed take-off of quantities of materials for cross-reference with SPONS financial data providing an agile and visual interface.

In order to begin the process of optioning iterations of house layout, multiple layouts across three storeys were created in AutoCAD. Each floor plan would need to provide compliant vertical circulation and services, e.g. aligned structure and stairs, and ensure that access is provided to all rooms regardless of room arrangement. This led to the creation of the following numbers of room iterations: ground floor *71* possible iterations of layouts, first floor *84* possible iterations of layouts, second floor *71* possible iterations of layouts. In combination, this provides *423,444* possible layouts, but it is worth noting that some of these may not be useful based on repetition across multiple floors, e.g. bedrooms on all floors (Figure 3).

3.2 Lifetime Pathway Outcomes

In combining the possible outcomes of the script, variables including the number of bedrooms, car ownership, size of kitchen and living rooms were factored into the Dynamo Study to provide 'live' updates of costing for demolition, renovation and alteration on the basis of lifestyle changes. Options for layout were then visually presented to the user through the Generative Design Study interface, presenting the design grid, design table and parallel coordinates. The user then made a choice based upon a combination of costing, visual preference, functional compliance and personal choice.

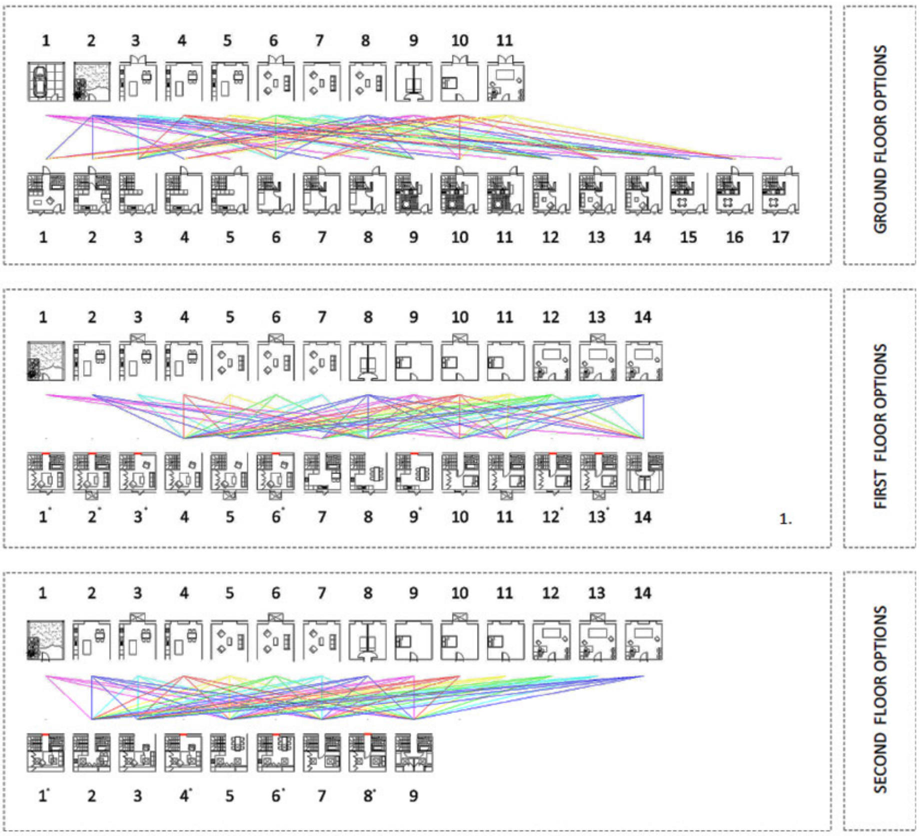

Figure 3: Floor layout options' front and 'back' across three floors (ground – first – second)

The chosen design was then imported into Rhino for the automated generation of plans, sections and elevations and to provide further material alterations based on user preference.

4 TESTING THE GENERATIVE DESIGN SCRIPT

The script was tested against the briefing requirements of six fictional families in the street, each with separate inter-generational living arrangements and budgets. The test outcome provided a dynamic mix of housing types to suit the diverse briefing of the homeowners. The model offered financial costings indexed to material quantities, allowing for inflation for speculative changes in future years.

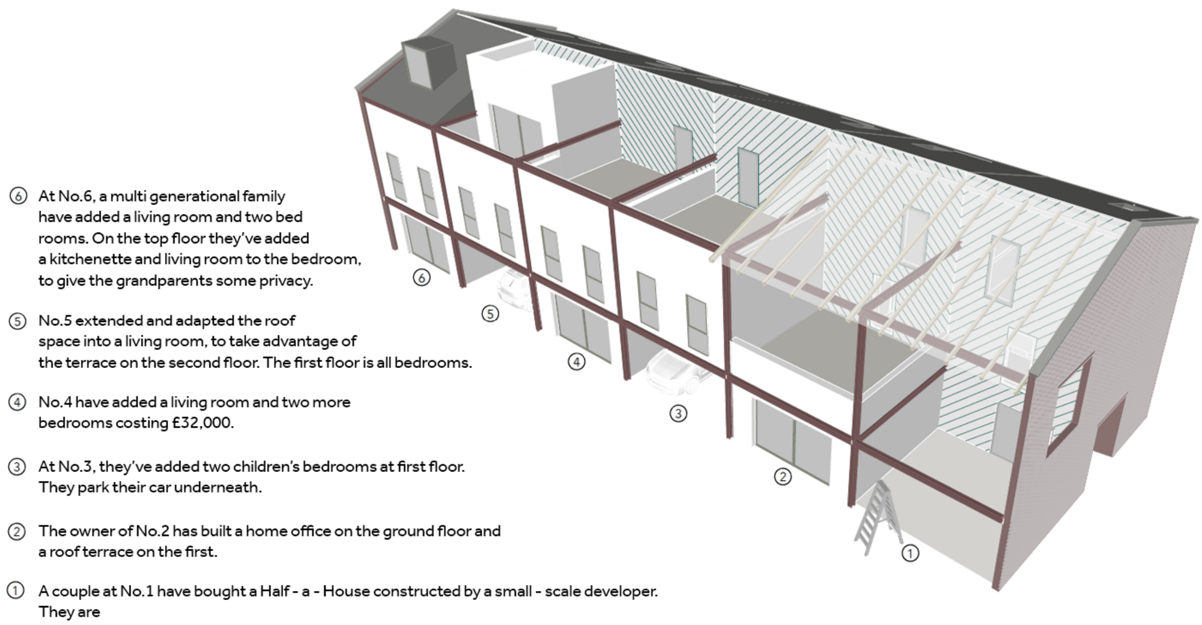

Figure 4: Speculation on the lifetime requirements of a diverse range of homeowners

The total cost for conversion for each family was compared to a sample of existing case studies of renovation and alteration for affordable housing. Although accurate comparisons of cost with built examples are complicated due to the significant variation between regional material availability and labour costs, the method does provide precise quantities that might be further broken down by a quantity surveyor and given regional or local bias dependent upon location.

5 CONCLUSION

The research has provided a methodology that successfully automates a multi-objective design generation algorithm for creating design iterations for multi-generational lifetime homes. Each homeowner was able to navigate design options generated to evaluate the potential cost of changes to the house based on their individual lifetime changes to improve forward financial planning. The work goes on to evaluate the effectiveness of the algorithm output by testing against the briefing requirements of a diverse multi-generational set of families across six houses. The results confirm that the method provides automated plan designs leading to improved outcomes for forwarding financial planning. User evaluation of the script demonstrates the method has the potential to deliver an innovative and architecturally successful product for first-time homeowners who wish to plan for a lifetime home.

Figure 5: Visualisation of the modular back-to-back street

The method has the potential to influence government policy on house building and through the positive application of forwarding planning for multi-generational housing alteration post-occupancy.

Figure 6: Visualisation of the modular back-to-back street

6 FUTURE WORK

Future work will explore applying the method to other building case studies, evaluating a variety of housing typologies in modular construction that vary in response to available land ownership and plot size. This work is currently underway in part: with the method being tested, refined and applied to layouts for both small-scale eco-housing in Preston and a new Garden Village development in Lancaster, which will deliver 3,500 new homes. It is intended that evaluation of the methodology will involve increased collaboration with quantity surveyors to advise on regional or site-specific variations in construction costings.

Finally, we hope that the work evidences the successful pursuit of the UN Sustainable Development Goals [5] and RIBA Sustainable Outcomes Guide [6]: to drastically reduce our carbon expenditure by planning whole-life carbon and promoting lifetime home living.

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