Abstract. Since the rise of generative design, a morphogenetic process of designing has emerged where algorithms are used to explore potential permutations of a solution to find the best design option. Yet, on a subjective level, identifying what option is considered best has often proven to be difficult. Hence, the paper discusses a foundation research to investigate prototypically subjective judgments concern matters of value and preference defined by end users in generative modelled urban design outcome. To do so the paper will introduce and outline research findings in the field of Micro-Economics, in particular its subcategories ‘Choice Modelling’ as a method and ‘Revealed Preferences’ as a methodology to assess whether user preferences can be identified and engaged as ‘preferred’ design options. In the paper the research will outline in greater depth the theories behind Choice Modelling and Revealed Preferences, a field that studies the behaviour of individuals, and its relevance for urban design, in particular Computational Urbanism. The paper discusses how Choice Modelling can analyse design outcomes and conclude and speculate about its use in an applied context.

Keywords. Generative design; Aesthetic judgment; Choice modelling; revealed preference; design evaluation.

1. Introduction

Since the rise of generative design, a morphogenetic process of designing has emerged where algorithms are used to explore potential permutations of a solution to find the best design option. As a result, designers have access to a tool that permits them to generate several potential design outcomes (Martin 2010). The designer is given the task of assessing and identifying which outcome out of the
generated options is superior to the rest. One can observe that this potentially can result in an open-ended process and hence one can ask how evaluation criterion can be established to narrow down and limit an open-ended design process? An open-ended process approach in design and the designer’s relationship to the generative process has been a long-standing topic of Greg Lynn’s ‘in-folding’ approach since the 1990s (Massumi 2000) but often in practice the open-ended design process must be terminated using either subjective or objective criterion.

1.1. COMPUTATIONAL URBANISM / PARAMETRIC URBANISM

Modern urban design is venturing towards that of parametric design where designers input various performance criteria and the building form is to be generated as a direct result of the inputs. Architecture and design is developing a data-driven design process where designing is no longer focused on the subjective decisions of the designer but rather the behavioural mannerisms of society and the surrounding context of the built form. As a result, urban planning and the creation of urban form is being developed according to “population thinking as opposed to typological thinking” (Verebes 2014) with the result being site specific, customised designs that are a direct reaction to the dynamic attributes of the urban context. Therefore, with the use of computational and parametric urbanism, it is now possible to contemplate the architectural shift from designing with aesthetic judgements to that of data-driven designing founded on objectivity and urban data. Observing that objective judgements can be addressed through computational and parametric urbanism one can asks where this leaves a subjective judgement of generated outcomes?

1.2. AESTHETIC JUDGEMENT

For the scope of this paper, a general description offers that objective judgements concern matters of empirical and mathematical fact whereas subjective decisions typically involve methods of value and preference (Mandik 2000). Objectivity can be weaved into the design process through parameters such as materials, sustainability, structure, manufacturing methods or cost constraints. Parameters discussed above that are subject to research are Grasshopper Plugins such as Ladybug / Honeybee and Karamba. Subjectivity, on the other hand, is more difficult to quantify as the values and preferences of the designer are intrinsically linked to their cultural, religious, social, and economic positions to name a few. With this in mind, design decisions are often made using subjective qualities. This paper questions how subjective design decisions could be understood and potentially generated computationally with computational and parametric urbanism.

In addition, this research also queries as to whether there currently exists a method (tool) and methodology (justification for using the tool) that bases the design decision process on user values and preferences.

1.3. RECOMBINANT GROWTH

In their 2016 book ‘The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies’ Erik Brynjolfsson and Andrew McAfee explain
the “Recombinant Growth” model developed by the economist Martin Weizman (1998) which, in short, is a mathematical model of a new growth theory that is not dissimilar to generative design. The theory offers an “innovation-as-building-block view, where both the knowledge pieces and the seed ideas can be combined and recombined over time.” (Brynjolfsson & McAfee 2016) The authors argued that Weizman’s “first generating new ideas, then filtering them” concept has now been widely applied by web-based start-ups due to readily available and affordable masses of data, vast computer power and the “more eyeballs” principles where the more participants looking at the same data, the more combinations can be discovered.

Weizman’s theory is relevant for this research as it provides the initiative background of the paper. After outlining Weizman’s theory, Brynjolfsson and McAfee describe a case study where the concept of “first generate new ideas, then filtering them” has been applied on evaluating a design. In the case study, Carlsberg breweries attempted to update the bottle and label for Belgium’s Grimbergen beer, the world’s oldest continually produced abbey beer. Carlsberg sought to update the brand but had concerns about damaging its reputation with a design change. His solution was to develop a method to better understand what the existing target market thought about the varying design options and which option was preferred. This case study founded on observation of user behaviour is directly linked to the level of research required for this project as users are able to choose their preferred design option out of numerous generated designs based on their subjective standpoint.

1.4. CHOICE MODELLING

Carlsberg, according to Brynjolfsson & McAfee (2016), employed ‘Affinnova’, a company “supporting recombinant innovation [who] helps its customers with the second of Weizman’s two phases: sorting through the possible combinations of [innovation-as] building blocks to find the most valuable ones.” Affinnova made use of the mathematics of Choice Modelling in order to sort through the design options. The Authors explain that:

“Choice modelling quickly identifies people’s preferences - do they prefer a brown embossed bottle with a small label, or a green non-embossed one with a large label? - be repeatedly presenting them with a small set of options and asking them to select which they like best. Affinnova presents these options online via the Web and can pinpoint mathematically, the optimal set of options (or at least come close to it) after involving only a few hundred people in the evaluation process. For Grimbergen [Affinnova’s client] (2013), the design that resulted from this explicitly recombinant process had an approval rating 3.5 times greater than that of the previous bottle.” (Brynjolfsson & McAfee 2016)

Based on the Carlsberg case study, one could conclude and propose the following research investigation to develop a subjective evaluation model for generative design, stating that:

If Choice Modelling can identify on a subjective level which, out of multiple design options, is the most approved beer bottle design, then one could potentially
adopt this method to identify on a subjective level, the ‘best’, or most ‘fit’ option of multiple generated design outcomes.

Thus, the paper discusses a foundation research to propose the generative modelling of urban design founded on subjective judgement, in particular, the values and preferences of the designer. The research will use ‘Choice Modelling’ as a method and ‘Revealed Preferences’ as a methodology to assess whether user preferences can be identified and engaged as ‘preferred’ design options. Both Choice Modelling and Revealed Preferences are subcategories of the field of Micro-Economics; a field that studies the behaviour of individuals (Bade & Parkin 2001) and are introduced and outlined in the following paragraphs.

2. Choice Modelling

Choice Modelling, as outlined by econometrician Daniel McFadden (2000) in his Nobel Prize lecture in Economic Science, is the “micro-econometric analysis of choice behaviour of consumers who face discrete economic alternatives”. It uses either ‘stated preference’ or ‘revealed preference’ techniques that are used to estimate non-market environmental costs and benefits (Bennett 2005).

2.1. STATED PREFERENCE

A ‘stated preference’ involves questioning a group of people regarding their preference for varying resource management strategies. Each question asked is termed a ‘choice set’ (Bennett 2005) and is only one outcome chosen out of generally three or four alternate strategies. Each choice set is grouped by a common set of attributes. Each alternative has one constant that is included in all choice sets, and the remaining attributes are altered to provide variety to the question being asked. Respondents are provided with two alternatives, with their choice of preferred alternative demonstrating their willingness to choose one attribute over another. For example, in the case of a cost-benefit analyses, if one alternative is monetary, it is possible to estimate the respondent’s willingness to include non-market environmental benefits described by the other attributes suggested (Bennett 2005).

2.2. REVEALED PREFERENCE

Revealed preference on the other hand, is a method of analysing choices made by individuals through their purchasing and consuming behaviour (Samuelson 1938). Where Stated Preference are mostly individual interviews based on a selected preference, i.e. asking the interviewee to view one or two images and asking them which of the two they prefer, Revealed Preference techniques attempt to understand consumer behaviour and the existing and past constrains on the individual such as their budget or particular interests such as visits to a certain webpage.

2.3. DISTINCTION BETWEEN BOTH AND MOTIVATION TO CHOOSE REVEALED PREFERENCES

Choice Modelling adopts both revealed and stated preferences. One can differentiate best by stating that revealed preferences are already made by the individual in the past (thus revealing what they have chosen prior) and stated preferences
documents choices made under experimental conditions (thus stating what preference exists at present). Given the increased ability to digitalise data and big data (Brynjolfsson & McAfee 2016) and the research’s interest in computing and automating processes, the following research will focus on revealed preferences as these are potentially already in existence and can be accessed through governmental or economical survey platforms, i.e. bureau of statistics in various countries.

Regardless, both sets of preferences are highly dependent on understanding human choice behaviour.

2.4. UNDERSTANDING HUMAN CHOICE BEHAVIOUR

A fundamental aspect of economics is understanding human choice behaviour (McFadden 1973). This task proves to be difficult as each act being observed is under the influence of external factors that cannot be controlled. The solution, as developed by Daniel McFadden, is to “make statistical inferences on a model of individual choice behaviour from data obtained by sampling from a population of individuals (or sampling from a population of experience levels) for a single individual” (McFadden 1973, pp 105).

The selection criteria for Choice Modelling consists of the objects of choice and sets of alternatives available to decision-makers, the observed attributes of decision-makers, and the model of individual choice and behaviour and distribution of behaviour patterns in the population. (McFadden 1973, pp 106)

The process of designing and implementing a Choice Modelling experiment is outlined by Bennett as follows:

1. Define the issue - interaction with bio-physical scientists
2. Define the attributes - including via focus groups with respondents
3. Define the levels
4. Select an experimental design
5. Design the questionnaire
6. Implement the survey
7. Data analysis
8. Report compilation (Bennet 2005)

2.5. CONCLUSION CHOICE MODELLING

Based on the Choice Modelling introduction above, the paper argues that there is great potential to combine the ability to document subjective opinions using Choice Modelling with the analysis and digital generation of urban form. This paper outlines our interest in designing and implementing Choice Modelling questionnaires to the public realm to define which urban design aspects are favourable over others, whether it be the building form itself, aspects of street frontage, varying facades and so on. Choice Modelling techniques permit the potential to combine the subjectivity of personal opinion with the objectivity of mathematics and parametric design to generate an infinite amount of urban designs founded on the likes of the public.
3. Implementing Choice Modelling

Global marketing research and analytical consulting firm Decision Analyst have implemented the Choice Modelling technique as well as a large range of modelling and simulation projects across a variety of industries including retail, restaurant, automotive, high-tech, and health. They employ an array of measurements and experiments in a "cause and effect" style of working to find the "underlying truth" (Decision Analyst 2016) and the "real reasons for consumers’ buying decisions" (Decision Analyst 2016). They conduct experiments that contain a predetermined set of realistic conditions such as asking the consumer which brand they would buy of the same product. These brands are presented visually and in the appropriate context of advertising, pricing, packaging, features, promotion, and other variables (Decision Analyst 2016) and often help in the optimisation of product designs, price sensitivity, brand strategy and more.

![Cellular Phone DecisionSimulator™ Demo Version 1.3](image)

Figure 1. Example of the DecisionSimulator system interface (Decision Analyst 2016).

This method of analysis is effective as it is “tailored to the specific objectives and constraints of each brand” (Decision Analyst 2016) and can be utilised to explore a variety of marketing scenarios (figure 1). Their findings are placed into a programmed Simulator that the company has developed that permits ‘what-if’ style scenarios to be explored through the simple entering and configuring of inputs. The benefit of this Choice Modelling technique is that consumers are able to provide information deeper than the simple ‘what they will buy and what they will not buy’. Choice Modelling permits the gathering of information of the roles of price, brand image, brand name, media advertising and an unlimited range of attributes that have a role in the decision making of the consumer. With this information, it is possible to explore new product designs, marketing strategies and an adjusted method of attack.
4. Issues Associated with Choice Modelling

In creating these Choice Model designs however, there is the issue of determining the number of alternative choice profiles to be offered in each choice set (figure 2) (Bennett 2008). Choice Models have the capacity to offer multiple alternatives within a single choice set, therefore the selection of a particular set of options is critical and is to be selected according to the desired outcome of the study. The number of choices offered to the respondent is purposely limited in a means to avoid burdening the respondent with complex choices (Bennett 2008). This often ensues in the minimisation of the description of choice profiles to only a limited number of attributes (figure 3). The negative impact of this may include reducing a complex cognitive task into something simpler that may not be as effective in representing the task. In the case where there are many attributes and levels involved, there is an inclination to reduce the number of profiles offered for selection in the choice model in a means to limit the cognitive task (Bennett 2008). The importance of this is evident in the decision-making process of the respondent as tasks too complex to consider may result in the deferring or avoiding of choices.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Cost</td>
<td>Amount that households would pay in extra rates (or rent) each year to fund improvements</td>
</tr>
<tr>
<td>Vegetation</td>
<td>% of healthy vegetation remaining in floodplains</td>
</tr>
<tr>
<td>Waterways</td>
<td>Kilometers of waterways in catchment remaining in good health</td>
</tr>
<tr>
<td>People leaving</td>
<td>Number of people leaving country areas each year</td>
</tr>
<tr>
<td>Reserve</td>
<td>% of water resources in catchment not committed to the environment or allocated to industry/urban/irrigation uses</td>
</tr>
<tr>
<td>Age</td>
<td>Age of respondent (in years)</td>
</tr>
<tr>
<td>Member</td>
<td>Dummy coded (1 if member of organization associated with environmental conservation)</td>
</tr>
<tr>
<td>Education</td>
<td>Dummy coded (1 if respondent has post-secondary qualification)</td>
</tr>
<tr>
<td>Income</td>
<td>Income of respondent</td>
</tr>
<tr>
<td>Gender</td>
<td>Dummy coded (1 if respondent was male)</td>
</tr>
<tr>
<td>Farming</td>
<td>Dummy coded (1 if respondent or family member associated with farming)</td>
</tr>
</tbody>
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Figure 2. Example of variables used as regressors in CM models (Rolfe & Bennett 2008).
5. Next Steps: Linking Choice Modelling to Generating Urban Design Outcomes

This paper is the beginning of an extensive study into the combining of Urban Design with Computational Urbanism through the methods of Choice Modelling and revealed preferences. In the case of this proposed research, we are proposing the use of the econometric methods of analysis of user behaviour to urban design where the consumers are developers who aim to identify which design, out of the generated proposed urban design options, possesses the most promising economic alternative (preferred by public).

Combining Choice Modelling with the generation of urban design outcomes has enormous potential in the development and proposal of design solutions where it provides an option to tailor designs to the demands of the public. The analysis of public requirements and desires in relation to urban design is possible through Choice Modelling, as demonstrated through this paper and in particular in the Carlsberg Case study. Whilst the case studies mentioned above are predominantly
related to brand and product marketing, this paper aims to extend the same principles used to the urban design field.

Choice Modelling can be implemented into the early stages of design development by providing end users with variations of generated designs, placed in a real-world situation. This could be presented through the lens of a Virtual Reality headset or perhaps a photoshopped image. The next step would then be to ask them to choose which design option is preferred according to their subjective opinion and documenting the findings. Extensive case studies of this would then be documented into a data pool and used as a base set of data for a machine learning algorithm where the subjective decisions of the end-user could be analysed, learned, and eventually repeated without the need for human interaction for future urban designs.

The resulting analysis can be implemented into early stages of design development and can act as a tool to reduce planning delays associated with developments and design proposals. Consumer retaliation and feedback is often provided at a stage that is post concept-design. Any changes required to be made due to public feedback are often provided after the document set of drawings is produced and presented, making it a time-consuming process to change any aspect of the design post-production. Using Choice Modelling to provide community feedback at an early design stage is therefore crucial in reducing any negative feedback that occurs after a development proposal is lodged. The earlier that consumer feedback can be incorporated into the design, the smoother the transition the project is submitted through the development approval process and hence the shorter the planning delay.

The combining of Choice Modelling with urban design would in our understanding involve the following process:

- Defining of an area to research (suburb or urban space)
- Finding the target market and outlining what data best describes the preference of a homebuyer looking to purchase in the specified area hence using already revealed preferences.
- Define and compare the desired urban design attributes to be analysed
- Develop an experimental Choice Model based on the chosen Revealed Preference values.
- Generate urban design outcomes using the outcome of the Choice Model analysis.
- Implement existing data (GIS / e-planning) as well as revealed preferences / choices already-made by individuals (statistics and house preference data) into the above model to further the accuracy of the design outcomes. This would be achieved via a software program that can access the webpage and its relevant data.
- Create an extensive data depository of e-planning, statistical and spatial data that is accessible online via a webpage.
- Develop and generate a set of designs based of this new data utilising VR and image processing as a method to display designs
- Test out each set of designs using Choice Modelling methods and document the resulting data.
Apply this data into a Machine Learning algorithm to analyse, learn and repeat the subjective design decisions made by the end-user.

It becomes evident that there is great potential to combine the subjective values of human design decisions into the automated process of digital design generation using Parametric controls. The urban design and development process is able to be streamlined with the incorporation of community involvement at early design stages using Choice Modelling analysis techniques. The benefit of this process is enormous as not only does it shorten planning delays, but urban designs are more readily and easily integrated with the desires of society. This generation process provides a gateway to combine the requirements of the community to the world of design and architecture with the ability to use real live data to influence and drive design decisions.

References


McFadden, D.: 2000, Modeling the Choice of Residential Location, Department of Economics, Massachusetts Institute of Technology, Cambridge, 1, 72-78.

McFadden, D.: 2000a, Econometric Analysis of Qualitative Response Models, Department of Economics, Massachusetts Institute of Technology, Cambridge, 1, 1395-1457.


