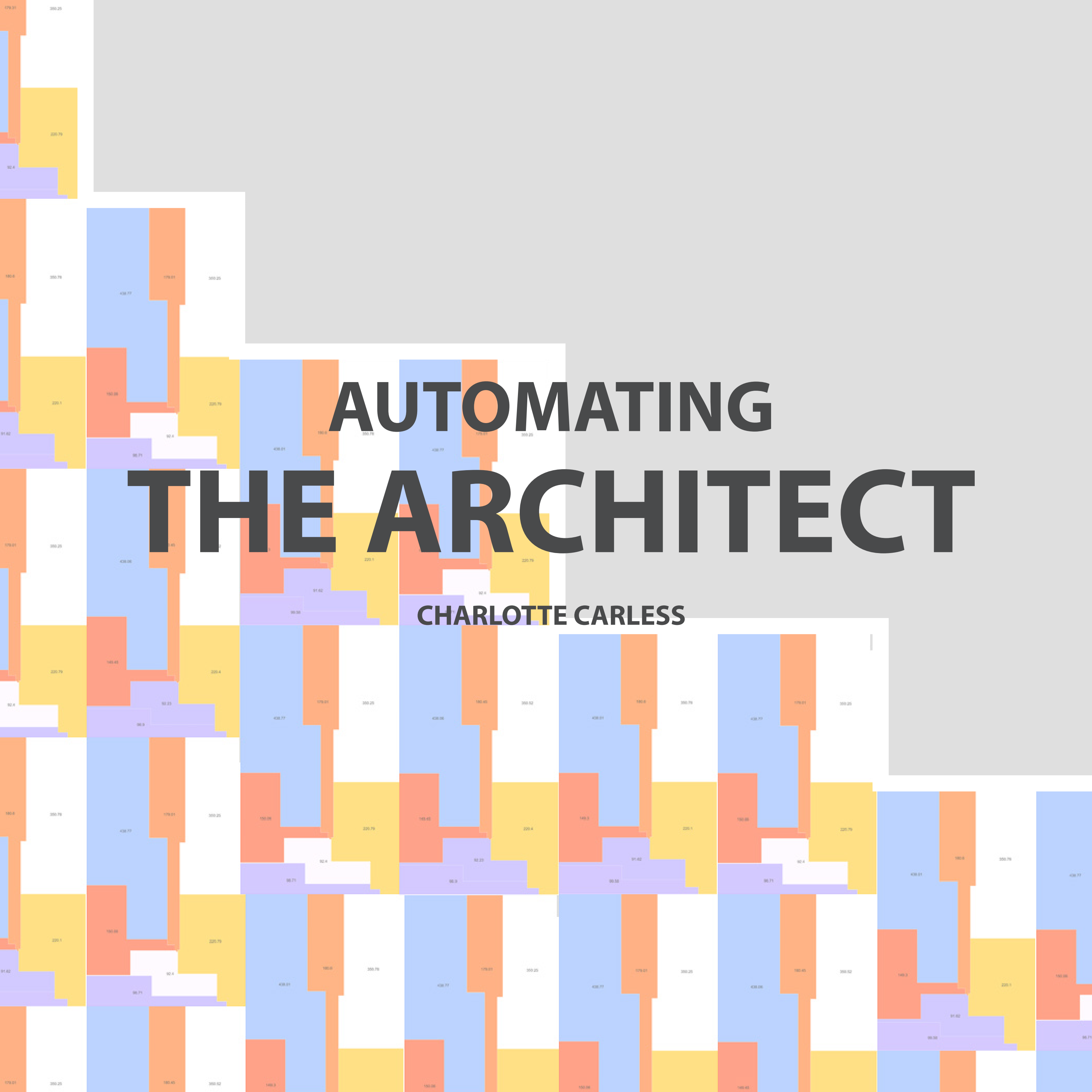

AUTOMATING THE ARCHITECT

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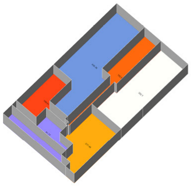
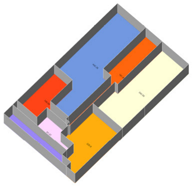
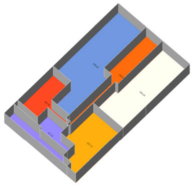
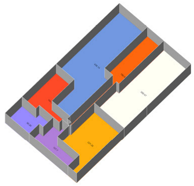





CONTENTS

ABSTRACT

Automation and technology are two of the biggest factors driving changes in the way we work. Studies estimate that 47% of occupations are susceptible to automation. Often predicted is that the role of the architect will remain in the future but what isn't discussed is how it could change. This thesis aims to predict how automation will affect architects. It will do this by first undertaking research into the technological advances architecture has seen, from the introduction of computer-aided design to most recent computational techniques. Following this, it will map the current working pattern of an architect through interviews conducted with architects on the tasks they complete during the RIBA Stages of Work. By developing a system to rate the automatability of design tasks it then rates each RIBA stage in regards to how susceptible they are to computerisation. The thesis then focuses on one stage of work and applies this rating scale to each task completed. Using the visual scripting design tool Grasshopper, it will attempt to automate one task. This test aims to predict what architectural tasks can be automated and how this will change the design process. In doing so, it aims to contribute to architectural knowledge with an insight into the future of the profession.

INTRODUCTION

'The computer and the digital have become the central mitigating factor in society, and we cannot conceive a world outside this matrix'[1]

Since the introduction of MIT's Sketchpad' in 1960, architects have used computer-aided design software to develop their projects. In 1983 Autodesk released AutoCAD which is still one of the most popular design programmes within architecture. The most recent development in architecture is computational design, where architects can use algorithms and software to design their buildings. As computer technology advances outside of architecture, it introduces automated machines that can function with very little human interaction. Since the industrial revolution in the 1700's, improvements in technology have changed the nature or need for many jobs.

According to a study published by Oxford University in 2013, Carl Benedikt Frey and Michael Osborne predicted that 47% of occupations were susceptible to replacement by automation[2]. Furthermore, the World Economic Forum estimates that between 2015 and 2050 7.1 million jobs worldwide will be lost to automation[3]. While it attributes a replacement rate of 1.8% to architects due to the high level of human interaction and low repetition, it is inevitable that automation will have a profound effect on the construction and architecture industry. The next era of digital technology will undoubtedly change the way architects operate. Take the introduction of BIM, for example, it required a new set of software skills and transformed the way architects design and document a building.

[1] Testa P. et al. 2017. **Robot House.** London. Thames and Hudson Ltd, p. 27.

[2] Frey, C & Obsorne, M. 2013. **The Future of Employment: How Susceptible are jobs to computerisation?** University of Oxford.

[3] World Economic Forum, 2016. **The Future of Jobs. Global Insight Challenge Report**

So what about the 1.8% replacement rate? Although technology introduced BIM which allowed for greater connectivity between governing bodies, architects, engineers and construction, there is still little within the architectural role that has been replaced by machines. Most recent predictions sit as a reassurance to architects that their role will remain futureproof. Automation creates a level of anxiety amongst professions, and there are little attempts to predict how computers could replace architects. This thesis will explore the current working pattern of an architect and critique areas that allow for the introduction of machine automation.

Although there is little knowledge on whether machines could replace architects designers have long been developing ways in which computers could design buildings. One example is the book by Nigel Cross (1977) 'The Automated Architect'[4]. Cross recognised in his MSc dissertation the opportunity technology introduced for machines to carry out the routine procedures of an architect, thus liberating him to focus on more design-based tasks.

'Programmed to proceed as far as possible without human intervention at each step, the computer would ask for decisions as required . . . We should be moving towards giving the machine a sufficient degree of intelligent behaviour, to liberate the designer from routine procedures and to enhance his decision-making role'[5] (Cross, 1967)

In his book Cross undertakes a detailed set of case studies on the development of computer-aided design programmes. Following with a discussion on 'humans versus machines', he quotes Negroponte[6] when referring to the desire to create a symbiosis between machine and man. He goes further to conduct a series of controlled experiments that record the results of questions concerning room layout and achieving minimum costs asked both to human designers and machines.

[4] Cross, N. 1977. **The Automated Architect.** London, Pion Limited.

[5] Cross, N (1967). **Simulation of Computer Aided Design**, MSc Dissertation, University of Manchester

[6] Negroponte's ideas of the architecture machine portrayed by Nigel Cross. It was primarily related to the architectural process; that the architecture machine was a computer who might have a human partner, but which might also be a designer in its own right Cross, N. 1977. **The Automated Architect**. London, Pion Limited.

Cross recognised that his predictions on CAD behaviour would be misleading, as the very introduction of them would lead to a shift in existing design processes. He conducted his research at a point where CAD systems were in their infancy, many of his results found a low improvement percentage between computer results and human results. It is possible that this factor was a principal reason for his prediction that 'computer-aided architectural design systems may have wide effects but limited effectiveness' (Cross, 1977).

Despite the prediction by Cross that design systems would have limited effectiveness, most architects today use some form of CAD system. A widely recognised benefit is their extending of the designer's abilities. In May 2011 the government published the Construction Strategy which in turn required all public centrally-procured government projects to be collaborative with building information modelling (BIM). As of 2016 these projects now needed to be at a maturity level of BIM Level 2, this requires all project and asset information, documentation and data to be electronic[7]. BIM is the first significant change architects have seen to their work process as it is a result of technological developments.

The current definitive model for construction and design in the UK are the RIBA Stages of work, a set of 8 work stages with details of tasks to be completed at each stage[8]. Recognising the changes BIM had on the construction process the digital project lifecycle[9] *(Figure 2)* was introduced by BSI (British Standards Institution) in their document PAS1192-2:2013. A collaborative team designed the digital project lifecycle, including members from the RIBA and they are the stages of work for a BIM level 2 project. While this also introduced resources such as the BIM Toolkit by NBS[10], it does not recognise the changes technology could have on the actual tasks of an architect.

The core system of software used in construction is a product of architectural knowledge. Written by Christopher Alexander is the book 'A Pattern Language'[11]. He devised a set of tools in which architects can design based upon the relations of things, rather than just things alone.

[7] **BIM Level 2,** Frequently Asked Questions. Department for Business, Energy & Industrial Strategy. Available online at: http://bim-level2.org/en/faqs/

[8] The current **RIBA** plan of work was revised in 2013 and is the definitive UK model for the building design and construction process. Available online at: [https://www.ribaplanofwork.com/]

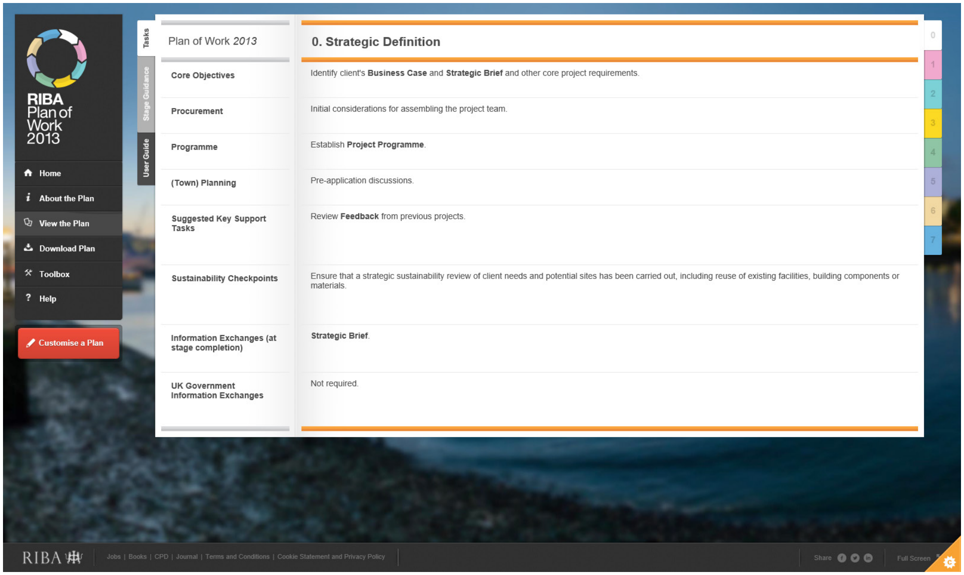
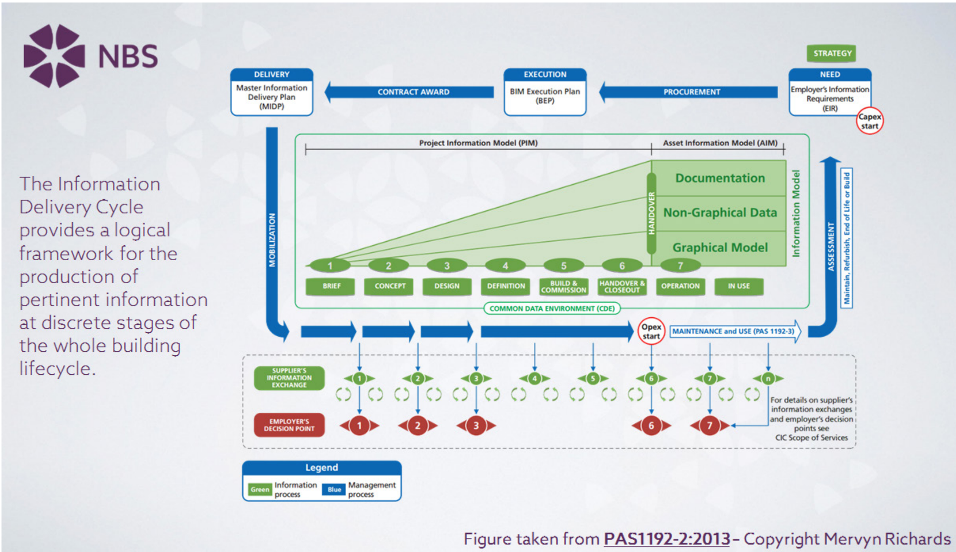


Figure 1, The RIBA Stages of Work, 2013. Online webpage for the most up to date customisable plan tools.



[9] *Figure 2,* **Digital Plan of Work** found in the BSI PAS 1192-2:2013 Specification for information management for the capital/ delivery phase of construction project using building information modelling.

[10] NBS, **BIM Toolkit.** Available online at: https://www.thenbs.com/services/our-tools/nbs-bim-toolkit

[11] Alexander, C. 1977. **A Pattern Language.** New York, Oxford University Press.

The book contains 253 patterns that analyse common problems within towns and buildings and offer solutions that form together in any chosen configuration to devise a 'language'. Describing the book as a 'manual, or a teacher, or a version of a possible language'[12] he provides the research as a 'base map' for the generation of new adaptable and individual project languages.

'We may then gradually improve these patterns which we share, by testing them against experience: we can determine, very simply, whether these patterns make our surroundings live, or not, by recognising how they make us feel"[13] (Alexander, 1979)

It is no surprise that breaking down a system into these patterns influenced software developers and the very operating systems that power mobile phones, computers and software today are developed using a variation of a 'pattern language'. Alexander himself refers to the language as a network saying 'since the language is in truth a network, there is no one sequence which perfectly captures it'[14]. By understanding the patterns of human behaviour, software engineers can develop a language suited to the technology they are creating. Software developers use a series of hierarchal decisions and behaviour trees, much of which follows the patterns of human beings. This thesis sees design in software as a translation of these patterns into 3D; it considers the evolution of 2D modelling software into 3D visual software as the improvement of patterns in how we design.

As cities become increasingly more complex, the systems we use to design the architecture they consist of needs to develop with mirrored complexity. Recognised by Tom Verebes the 21st-century city requires a new conceptual and methodological apparatus[15], discussed in his book 'Masterplanning the Adaptive City' (2014) are the new tools for computational design.

'Parametric and algorithmic methodologies are powerful tools for generating organisational heterogeneity and spatial variation and differentiation.' [15] (Verebes, 2014)

[12] Alexander, C. 1977. **A Pattern Language.** New York, Oxford University Press.

[13] Alexander, C. 1977.

[14] Alexander, C. 1979. **The Timeless Way of Building**. New York, Oxford University Press.

The new tools for design, as discussed by Verebes, start with the increasing knowledge and development of parametric design and code-based design. These technologies not only give us the ability to add and erase but to add, erase, relate and repair (Woodbury 2010)[16]. We have algorithms that can search for solutions in defined space and the ability to comprehend the increasing complexity of data in our cities. Addressing the present status of parametric design for urbanism Verebes describes the relation of the architect to data and software as 'essentially learning a new language'. He touches on open-source code in shared libraries and wikis on the internet. Noticing the collaborative shift computational design is orchestrating within architecture.

'Codes – planning codes, social or cultural codes, computational programming language – change over time; the natural evolution of cultural, social, political, and technological apparatus necessitates equally adaptable tools with which to design and manage complex urban order'[15] (Verebes, 2014).

[15] Verebes, T. 2014. **Masterplanning the Adaptive City.** New York, Routledge

[16] Woodbury, R. 2010. **Elements of Parametric Design.** New York, Routledge. p.11

This thesis will be structured as follows, Part 1 looks at the current working routine of an architect to decide on what tasks could be automated. It consists of interviews with architects, mapping out their working day followed by a closer inspection of the tasks in one stage. In addition to this, it looks at the tasks in each RIBA Stage of Work and how susceptible they are to automation. It does this by analysing how the technology readiness levels (TRL's) operate and introduces a series of Automation Readiness Levels (ARL's) to assess the different tasks. In doing so, it aims to provide the basis for an informed decision on which task the thesis will try to automate.

Part 2 will test if the chosen task, room layouts, can be automated using the architectural scripting tool Grasshopper. The first step is to define what the algorithm will be aiming to automate. Following will be the writing of an algorithm that can compute this information, this is an iterative process, and this thesis only records the successful algorithm. The results will then be recorded from the Rhino 3D model space and critiqued regarding their successfulness.

Part 3 will consist of a series of conclusions predicting how this changes the role of the architect. The first will be a revised set of RIBA work stages that include technical tasks and evolved design tasks. The conclusion will then examine how the tests in this thesis can be applied to a larger scope of architectural design. It will focus primarily on the effects automation will have on the architecture profession. Followed by a personal reflection from the author.

PART 1 - IDENTIFYING THE TASK

Part 1 looks at the current working routine of an architect to decide on what tasks could be automated. It consists of interviews with architects, mapping out their working day followed by a closer inspection of the tasks in one stage. In addition to this, it looks at the tasks in each RIBA Stage of Work and how susceptible they are to automation. It does this by analysing how the technology readiness levels (TRL's) operate and introduces a series of Automation Readiness Levels (ARL's) that are used to assess the different tasks. In doing so, it aims to provide the basis for which task the thesis will try to automate.

The question of 'what can a computer not do' is harder to answer than the question of what a computer can do. As we approach an age of technology anything repetitive can be auomated. This thesis begins by asking questions surrounding artificial intelligence and its ability to imitate more complex patterns of human behaviour. It takes a chronological analysis of the developments made in computer-aided design (CAD) and highlights the current predictions technology have on the future of architecture. Highlighting the lack of knowledge into how automation changes the nature of design, it looks explicitly into how automation affects the working pattern of an architect and rather than predict it will replace designers it asks how one changes the nature of the other.

The thesis establishes the working routine of an architect through a series of interviews. Focusing on questions framed around the RIBA stages of work the interviews will be used to write a series of timelines depicting the current architectural process. Understanding how the maturity of new technology is evaluated and the variables to determine how automatable a task is, the thesis establishes a new rating system. These are levels designed to rate architectural design tasks and their risk of computerisation. Using these levels and the information gathered in the interviews it will then critique each stage of the RIBA Plan of Work. The thesis then highlights one RIBA stage to evaluate and makes an informed decision on what task part 2 aims to automate.

By breaking down the chosen task into a set of variables and inputs, the ability of a computer to automate a certain point in design will be tested using the visual scripting plug-in Grasshopper. The thesis uses the plug-in for the CAD programme Rhino as it provides a designer with an interface for building algorithms that generate geometry in Rhino modelspace. Using a set of numerical inputs and algorithms this work will speculate on how a task carried out by an architect may be carried out by a computer.

The thesis will look at texts on technology and artificial intelligence, aiming to fill a gap in architectural knowledge and address how automation will change the nature of the architectural role. In conducting a test into how a computer could carry out a design task, the research will follow with a prediction into how it could change the profession and alter the RIBA Stages of Work. By predicting how the work stages could change it aims to provide critical insight into how architects may work in the future and how they stay relevant as the ability of automation increases.

THE CURRENT WORKING PATTERN OF AN ARCHITECT

1.1 -
INTERVIEW PROCESS

Section 1.1 starts by establishing the workflow of an architect. In order establish this a series of interviews with architects are carried out. The findings of which are written into two timelines and organised according to the RIBA Stages of Work. These were done to look for repetitive behaviour in the way architects work and to gain their opinions on the automation of their profession.

To be able to decide on how architects could be automated the first step is to develop an understanding of the tasks they carry out. This thesis develops that understanding by carrying out a series of interviews with architects. The interviews were intended to gain a certain level of granularity into the individual tasks throughout a design project. To further write the algorithm in this thesis, an organised set of behaviour is required to describe the task that will be automated[17]. This section aims to gather the information on those tasks.

Currently, architects in the UK work within a defined framework set out by the Royal Institute of British Architects (RIBA). The interview questions were intentionally structured to gather detail of the tasks at each stage. The current RIBA Stages of Work 2013 (SoW, Figure 3) 'comprises of eight work stages, each with clear boundaries and details the tasks and outputs required at each stage[18]'. First developed in 1963 it is the definitive model for construction and design in the UK. Its most recent revision in 2013 superseded the 2007 version which is now available online to customise. The interviews were not only crucial in gaining detailed responses to how architects work within these stages, but also in obtaining opinions on what they thought about the automation of their profession[19].

[17] Knowlege on algorithmic design was gathered prior to the writing of the thesis algorithm. Kleinberg, J., Tardos. E. 2006. **Algorithm Design.** United States of America, Pearson Education Inc. p.2

[18] The current **RIBA** plan of work was revised in 2013 and is the definitive UK model for the building design and construction process. Available online at: [https://www.ribaplanofwork.com/]

[19] Interview questions can be found in Appendix 6.0. Conversations were tailored to suit each interviewee during recording.

[20] Refers to the conversation with **Alastair Parvin,** the open source designer and Director of WikiHouse Foundation who specialises in digital innovation in architecture. Transcript can be found in Appendix 2.0

[21] Parvin, A. Appendix 2.0

The first interview was with Alastair Parvin[20], who is by his definition a 'strategic designer'. Parvin was chosen for this series of interviews as he is not only researching into open source architecture but is also a specialist regarding his knowledge of architecture and technology. He provided an insight into how technology is changing the design industry. He highlighted the need for architects to understand how to stay relevant saying **'the question is will architects be savvy enough to understand how this is working to participate in the conversation.'**[21] His interview provided an insight into how architecture as a profession has changed over the years and his opinions on how it will change in the future.

In a similar thread, the second interview was with Lauren Poon[22], an architect at CallisonRTKL. She is responsible for advocating the use of technology in her office. The author chose Poon for her knowledge of computational design and the use of building information modeling (BIM), which is the most recent technological push in architecture as a whole. She highlighted the need for architecture to adapt with technology saying **'measuring data points all the way through requires a complete restructuring of what our services are as an architect.'**[23] Her team are looking at computational design to solve spatial problems while providing the most value to the client.

The third interview was with an architect who works closely with the traditional stages of work. Jeff Kahane[24] is an architect and director of his practice. He prefers to traditionally work with card and paper models, while using CAD programmes such as Sketch-Up and Vector Works to produce 3D visuals for clients during the design stage. While noting he could not see a way in which automation could work with architects, he highlighted the developments fabrication techniques have seen. In his opinion **'automation and CNC cutters are amazing for design, you can produce the cad information, send it to a fabricator and get their prices, which means complexity costs so much less.'**[25]

[22] Refers to the conversation with Lauren Poon, architect at CallisonRTKL. Transcript can be found in Appendix 3.0

[23] Poon, L. Appendix 3.0

[24] Refers to the conversation with Jeff Kahane, and architect who works with minimal amounts of technology. Transcript can be found in Appendix 4.0

[25] Kahane, J. Appendix 4.0

Continuing to interview architects that don't predominantly use technology, the fourth interview was with William Beeston[26] from Publica. They have developed a unique way of understanding the public realm that focuses on the importance of time spent on site and specialise in developing a client brief for this. He discussed how automation could be used to do repetitive details saying **'I think we spend too much time on the larger projects detailing things and reinventing things.'**[27] He followed with the comment **'I think it should be more about designing spaces and I don't think many people get that, the nuance of space in particular public spaces.'**[28] His view on automation was that it would allow architects to focus on the importance of designing good spaces.

The thesis records the interview findings in two timelines, one with information from both technically focused architects and the other with the two more traditional architects (figures 4 and 5). These were structured using the RIBA Stages of Work and tasks were divided according to which stage they occurred. By dissecting the interviews into timelines, the findings were used to understand the different types of behaviour in the design process. In doing so it provides a framework to asses the automatability of each design stage.

[26] Refers to the conversation with William Beeston. Publica work within the earlier stages of the RIBA Plan of work. Transcript found in Appendix 5.0

[27] Beeston, W. Appendix 5.0

[28] Beeston, W. Appendix 5.0

RIBA Plan of Work 2013

The RIBA Plan of Work 2013 organises the process of briefing, designing, constructing, maintaining, operating and using building projects into a number of key stages. The content of stages may vary or overlap to suit specific project requirements. The RIBA Plan of Work 2013 should be used solely as guidance for the preparation of detailed professional services contracts and building contracts.

www.ribaplanofwork.com

Tasks ▼ / Stages ▶	0 Strategic Definition	1 Preparation and Brief	2 Concept Design	3 Developed Design	4 Technical Design	5 Construction	6 Handover and Close Out	7 In Use
Core Objectives	Identify client's **Business Case** and **Strategic Brief** and other core project requirements.	Develop **Project Objectives**, including **Quality Objectives** and **Project Outcomes**, **Sustainability Aspirations**, **Project Budget**, other parameters or constraints and develop **Initial Project Brief**. Undertake **Feasibility Studies** and review of **Site Information**.	Prepare **Concept Design**, including outline proposals for structural design, building services systems, outline specifications and preliminary **Cost Information** along with relevant **Project Strategies** in accordance with **Design Programme**. Agree alterations to brief and issue **Final Project Brief**.	Prepare **Developed Design**, including coordinated and updated proposals for structural design, building services systems, outline specifications, **Cost Information** and **Project Strategies** in accordance with **Design Programme**.	Prepare **Technical Design** in accordance with **Design Responsibility Matrix** and **Project Strategies** to include all architectural, structural and building services information, specialist subcontractor design and specifications, in accordance with **Design Programme**.	Offsite manufacturing and onsite **Construction** in accordance with **Construction Programme** and resolution of **Design Queries** from site as they arise.	Handover of building and conclusion of **Building Contract**.	Undertake **In Use** services in accordance with **Schedule of Services**.
Procurement *Variable task bar	Initial considerations for assembling the project team.	Prepare **Project Roles Table** and **Contractual Tree** and continue assembling the project team.	← The procurement strategy does not fundamentally alter the progression of the design or the level of detail prepared at a given stage. However, **Information Exchanges** will vary depending on the selected procurement route and **Building Contract**. A bespoke **RIBA Plan of Work 2013** will set out the specific tendering and procurement activities that will occur at each stage in relation to the chosen procurement route. →			Administration of **Building Contract**, including regular site inspections and review of progress.	Conclude administration of **Building Contract**.	
Programme *Variable task bar	Establish **Project Programme**.	Review **Project Programme**.	Review **Project Programme**.	← The procurement route may dictate the **Project Programme** and may result in certain stages overlapping or being undertaken concurrently. A bespoke **RIBA Plan of Work 2013** will clarify the stage overlaps. The **Project Programme** will set out the specific stage dates and detailed programme durations. →				
(Town) Planning *Variable task bar	Pre-application discussions.	Pre-application discussions.	← Planning applications are typically made using the Stage 3 output. A bespoke **RIBA Plan of Work 2013** will identify when the planning application is to be made. →					
Suggested Key Support Tasks	Review **Feedback** from previous projects.	Prepare **Handover Strategy** and **Risk Assessments**. Agree **Schedule of Services**, **Design Responsibility Matrix** and **Information Exchanges** and prepare **Project Execution Plan** including **Technology** and **Communication Strategies** and consideration of **Common Standards** to be used.	Prepare **Sustainability Strategy**, **Maintenance and Operational Strategy** and review **Handover Strategy** and **Risk Assessments**. Undertake third party consultations as required and any **Research and Development** aspects. Review and update **Project Execution Plan**. Consider **Construction Strategy**, including offsite fabrication, and develop **Health and Safety Strategy**.	Review and update **Sustainability**, **Maintenance and Operational** and **Handover Strategies** and **Risk Assessments**. Undertake third party consultations as required and conclude **Research and Development** aspects. Review and update **Project Execution Plan**, including **Change Control Procedures**. Review and update **Construction** and **Health and Safety Strategies**.	Review and update **Sustainability**, **Maintenance and Operational** and **Handover Strategies** and **Risk Assessments**. Prepare and submit Building Regulations submission and any other third party submissions requiring consent. Review and update **Project Execution Plan**. Review **Construction Strategy**, including sequencing, and update **Health and Safety Strategy**.	Review and update **Sustainability Strategy** and implement **Handover Strategy**, including agreement of information required for commissioning, training, handover, asset management, future monitoring and maintenance and ongoing compilation of **'As-constructed' Information**. Update **Construction** and **Health and Safety Strategies**.	Carry out activities listed in **Handover Strategy** including **Feedback** for use during the future life of the building or on future projects. Updating of **Project Information** as required.	Conclude activities listed in **Handover Strategy** including **Post-occupancy Evaluation**, review of **Project Performance**, **Project Outcomes** and **Research and Development** aspects. Updating of **Project Information**, as required, in response to ongoing client **Feedback** until the end of the building's life.
Sustainability Checkpoints	**Sustainability Checkpoint — 0**	**Sustainability Checkpoint — 1**	**Sustainability Checkpoint — 2**	**Sustainability Checkpoint — 3**	**Sustainability Checkpoint — 4**	**Sustainability Checkpoint — 5**	**Sustainability Checkpoint — 6**	**Sustainability Checkpoint — 7**
Information Exchanges (at stage completion)	**Strategic Brief**.	**Initial Project Brief**.	**Concept Design** including outline structural and building services design, associated **Project Strategies**, preliminary **Cost Information** and **Final Project Brief**.	**Developed Design**, including the coordinated architectural, structural and building services design and updated **Cost Information**.	Completed **Technical Design** of the project.	**'As-constructed' Information**.	Updated **'As-constructed' Information**.	**'As-constructed' Information** updated in response to ongoing client **Feedback** and maintenance or operational developments.
UK Government Information Exchanges	Not required.	Required.	Required.	Required.	Not required.	Not required.	Required.	As required.

***Variable task bar** – in creating a bespoke project or practice specific RIBA Plan of Work 2013 via www.ribaplanofwork.com a specific bar is selected from a number of options.

© RIBA

Figure 3, The RIBA Stages of Work, 2013

INTERVIEW TIMELINE 1

ALASTAIR PARVIN

LAUREN POON

This timeline maps the work flows of both Alastair Parvin and Lauren Poon in accordance with the RIBA Stages of Work.

These points were taken from the interviews with both in the initial research stage.
(interview transcript in appendix)
(figure 4)

PROJECT LIFECYCLE

Understanding working through a project from 2 technological perspectives:

AP - Open Source Entre-preneur
LP - Architect / Technology Expert

Figure 3

RIBA Stages

0 **Strategic Definition**

1 **Preparation & Brief**

2 **Concept Design**

3 **Developed Design**

4 **Technical Design**

5 **Construction**

6 **Handover & Close Out**

7 **In Use**

AP — Alastair Parvin

Socio & Political Aspects

The built environment is socially and politically charged. Understanding the key factors affecting the particular design will give architects pertinence in a tech focused design workplace.

Open Source Script

By designing the brief as a chaning system and not a static object changes can be input at multiple different levels and the design responds.

Pattern Design & Evolution

Knowledge of design patterns previously contained in books and developed in ages can be input into script.

Planning Permission

Can the stages and questions asked in a planning perimission application be automated and the process time frame shortened.

Design Based Engineering

Being able to make in house deci-sions that save money during fabri-cation and construction. Systems are managed by in house profesionals rather than out sourced.

In House Fabrication/ Construction

Open source design patterns mean anyone with knowledge of construction can download and build or modify the documents, placing ownership into the hands of the designer.

End user - Social politics

Understanding the user expe-rience in the built environment will be cruical to the longevity of the architectural role with technology.

LP — Lauren Poon

Appointment

The architects are appointed by the client.

Data Collection

Recieving data from the client either regarding to the site or the design specifications. Early stages set out how much data the client has.

Data Analysis

Input of client data into programmes. Parametric models and script are used in feasability stage now the data is readily available.

Data drop schedule

To manage a clients expectation data drops during the project timeline are scheduled.

Areas

Working with commercial clients means the biggest amount of data is on areas, cost and value flows can be produced with the clients data.

Parametric Analysis

Data can be input into a parametric model enabling developed design decisions to be made at an earlier stage .

Initial Design

Building layouts are drawn according to the clients brief.

Computational Design

Setting up a computational solver to work with a mass or a site and respond to design problems to give the most value.

Design Analysis Using Software

Maximising views to certain landmarks or lighting strategies using software to make the best design decisions.

Dynamo

Scripts used to measure parts of the design - the whole model not yet parametric.

Inputs / Outputs

Scripts used to output data from Revit into Excel, need to be sorted and checked by a member of the design team before issue.

Inputs / Outputs -

Whilst the computer can answer decisions based on data, human input is required to feed the programme with data.

Data Affected Decisions

Technical design decisions can be affected by data developed decisions made at the feasability stage

Data Sets

As data moves through dif-ferent programmes it needs to be checked, organised and reformatted.

Parametric Design

As the model is pushed through from Rhino and Sketchup through to Revit it is linked to Dynamo scripts.

Informed Contractors

Knowing early on the effects a change within the strucutral design has on the rest of the project including construc-tion means a more informed tender decision can be made.

Defect liability period

3 months on small projects, 6 months on larger and 12 months on some. Liabiity to return and fix and problems within this period.

PROJECT LIFECYCLE

Understanding working through a project from 2 non- technological perspectives:

JK - Architect / Director
WB - Architect / Public realm expert

Figure 4

RIBA Stages

0 **Strategic Definition**

1 **Preparation & Brief**

2 **Concept Design**

3 **Developed Design**

4 **Technical Design**

5 **Construction**

6 **Handover & Close Out**

7 **In Use**

JK (Jeff Kahane)

Appointment
Initial email from the client requesting services.

Engineer
Appointed early in small projects if there is a good working relationship.

Building Control Officer
Often appointed early to work through the building regulations

Client Meetings / Emails
Site information/ precedents in the local area. Feasability of project scope .

3D Models & Sketches
Card and foam models of concept design proposals/ sketches of possible scheme and layouts.

Computer Visuals
Sketchup visuals of the scheme early on for the client to see development

Final Design Scheme
Scheme design finalised and documents prepared for planning permission submission

Planning Permission
6 weeks to get planning permission for a small project, an extra month if it goes to comittee. No work on site unless client is prepared to risk extra fees if it isn't accepted.

M&E Engineer
Relevant consultants are brought into the project.

Tender Accepted
Once the tender has been accepted the client works out their budget accordingly

Site Meetings
During construction, if appointed by the client to stay on through this stage, the architect will attend site visits to over see the construction.

Defect liability period
3 months on small projects, 6 months on larger and 12 months on some. Liabiity to return and fix and problems within this period.

Energy Efficiency
It is possible to return to check the energy efficiency of proucts that have certain claims i.e lighting claims

Client Meeting 1
Initial client meeting, often with a visit to either their house or their site.

Fee Proposal
The fee proposal is sent to the client once the brief has been set.

Tender
Official period - 3/4 weeks comptetitive tender to gain prices from several different contractors.

Lighting Engineer
If the project requires sophisticated lighting an engineer can be called in to assist design.

WB (William Beeston)

Client Meeting 1
Initial client meeting, often with a visit to either their house or their site.

Site Visit 1
Initial site visit understanding the place/ photographs

Site Visit 2
Site visit/ photographs/ review of space

Site Visit 4
Site visit/ photographs/ review of space

Mapping
Overay the data on to maps of the site with indesign

Site Visit 5
Understanding how people use the space

Site Visit 7
Site visit/ photographs/ review of space

SpaceSyntax
The inclusion of data from SpaceSyntax to give the client solid data

Brief
Once the surveys are completed the client recieves a solid set of surveys/ work/ brief to enable them to address the public realm within their project

Local Authorities
Once the brief is set the client often moves on to either a landscape architect or local council

Handover
Advice can be offered on the further stages of the design process but it is recommended that an engineer is appointed due to liability reasons.

Appointment
Initial email from the client requesting services.

Client Meeting 2
Review their current proposal/ work and understand where it is lacking in addressing the public space

Client Meeting 1
Begin to establish their goals and what kind of brief they need

Client Meeting 2
Pitch to them the imporance of the service

Mapping
Overay the data on to maps of the site with InDesign

Site Visit 3
Site visit/ photographs/ review of space.
Look for existing data on the site. i.e TFL gate recording

Site Visit 6
Different nuances of the site are highlighted e.g. focuses on the active frontages etc

Site Visits
There is a strong importance to visit the space often and understand its properties socially within the built environment

Mapping
Overay the data on to maps of the site with InDesign

Precedent
Precedents of both designs that work well and designs that dont work well in similar public spaces are gathered for the client

NB* The company **Publica** focuses primarily on design tages 0-2

THESIS FOCUS

+ TASKS DERIVED FROM INTERVIEWS IN APPENDIX 3 & 4

INTERVIEW TIMELINE 2

JEFF KAHANE

WILLIAM BEESTON

This timeline maps the work flows of both Jeff Kahane and William Beeston in accordance with the RIBA Stages of Work.

These points were taken from the interviews with both in the initial research stage. (interviews transcript in appendix) *(figure 5)*

1.2

TECHNOLOGY READINESS LEVELS

Section 1.2 looks at the technology readiness levels (TRL's), these are a set of requirements established by NASA to measure how ready new technology is to enter a commercial environment. It then uses Frey and Osborne's variable indicators for bottlenecks to computerisation, taking a broader analysis into what factors determine how susceptible a particular behaviour is to automation. In doing so, it aims to understand what tasks identified in the interviews could be automated.

Definition:
Noun

Automatability
1. The quality of being automatable; the ability to be automated.

In order to communicate the maturity of new technology, a widely adopted approach is to use the 'technology readiness levels' (TRL's) [29]. TRL's were originally conceived at NASA in 1974 and formally defined in 1989. While there are widely revised versions for industries such as the Department of Defence (US) *figure 6* demonstrates the definitions used by NASA. It should be noted that the definitions vary for each sector to provide relatability to the different features of each organisation.

A TRL scale consists of nine levels, each of which represents a different technology maturity level. As the readiness level increases, the technology concept reaches a higher level of capability. As the capability increases, ensuring the technology is accepted and adopted by the workforce becomes a vital element[30]. To be deemed operational in a commercialised environment the technology is required to meet all criteria in the scale, including laboratory studies, simulations and working prototypes. Once a technology has been 'flight-proven' it can reach TRL 9, and it is ready for implementation.

"Technology Readiness Levels (TRL) are a type of measurement system used to assess the maturity level of a particular technology. Each technology project is evaluated against the parameters for each technology level and is then assigned a TRL rating based on the project's progress. There are nine technology readiness levels, TRL 1 is the lowest, and TRL 9 is the highest."[31]

[29] NASA, 2012. **Technology Readiness Levels.** Available online at: https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html

[30] Charalambous, G. 2016. **The development of a Human Factors Readiness Level tool for implementing industrial human-robot collaboration.** Cranfield University, UK.

[31] Frey, C & Obsorne, M. 2013. **The Future of Employment: How Susceptible are jobs to computerisation?** University of Oxford.

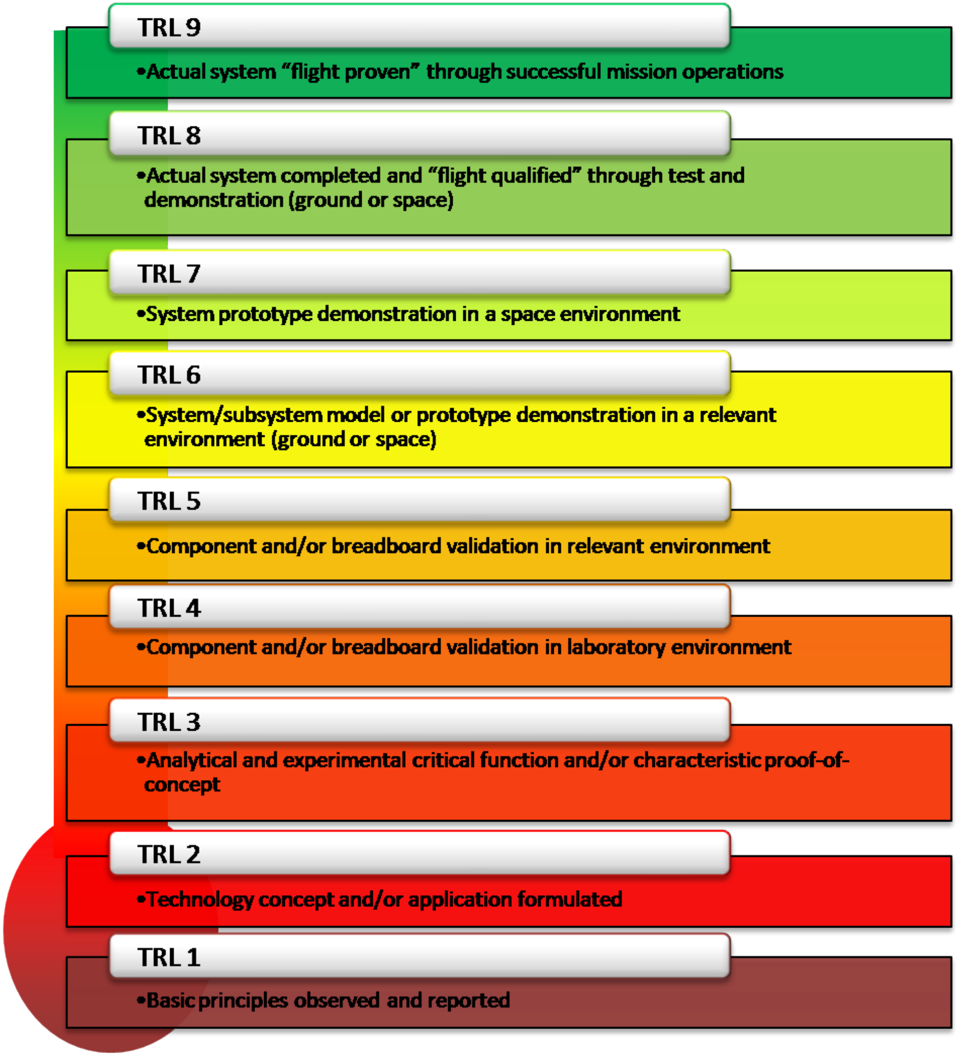


Figure 6. NASA, 2012.
Technology Readiness Levels.

Historically, occupations at the highest risk of computerisation were either manual or cognitive. 'Today, the problems of navigating a car and deciphering handwriting are sufficiently well understood that many related tasks can be specified in computer code and automated'[32]. In 2013, the study by Carl Benedikt Frey and Michael Osborne looked at how how susceptible employment was to computerisation. They devised a task model that incorporated big data and pattern recognition to predict that automation would not be confined to only routine jobs. Their variables for occupations non-susceptible to computerisation were social intelligence, creativity and perception and manipulation; *figure 7* is their identification of these variables.

In order to understand what parts of the design process could be automated a new rating scale is established. The automation readiness levels (ARL's) will consist of streamlined tasks conducted by an architect throughout a project. They will follow the same framework of the TRL's, composed of 9 levels that will rate how automatable a behaviour or task is. This framework will base its knowledge on the variables of computerisation derived by Frey and Osborne and tasks within the design process will be cross-referenced with their findings. The ARL's will provide a framework for assessing how susceptible a task is to computerisation. When applied to all tasks in the interview timelines they begin to demonstrate how the RIBA Stages of Work will change with technology.

[32] Frey, C & Obsorne, M. 2013. **The Future of Employment: How Susceptible are jobs to computerisation?** University of Oxford. p. 45

TABLE I. O∗NET variables that serve as indicators of bottlenecks to computerisation.

Computerisation bottleneck	O∗NET Variable	O∗NET Description
Perception and Manipulation	Finger Dexterity	The ability to make precisely coordinated movements of the fingers of one or both hands to grasp, manipulate, or assemble very small objects.
	Manual Dexterity	The ability to quickly move your hand, your hand together with your arm, or your two hands to grasp, manipulate, or assemble objects.
	Cramped Work Space, Awkward Positions	How often does this job require working in cramped work spaces that requires getting into awkward positions?
Creative Intelligence	Originality	The ability to come up with unusual or clever ideas about a given topic or situation, or to develop creative ways to solve a problem.
	Fine Arts	Knowledge of theory and techniques required to compose, produce, and perform works of music, dance, visual arts, drama, and sculpture.
Social Intelligence	Social Perceptiveness	Being aware of others' reactions and understanding why they react as they do.
	Negotiation	Bringing others together and trying to reconcile differences.
	Persuasion	Persuading others to change their minds or behavior.
	Assisting and Caring for Others	Providing personal assistance, medical attention, emotional support, or other personal care to others such as coworkers, customers, or patients.

Figure 7. Frey and Osborne's variables that serve as indicators of bottlenecks to computerisation.

1.3

AUTOMATION READINESS LEVELS

Section 1.3 uses the information gathered in the interviews and knowledge relating to technology readiness levels to establish a set of automation readiness levels (ARL's). This section rates different design tasks from 1-9 by how likely they are to be automated. The tasks at each stage are cross-referenced with the variables set out by Frey and Osborne. In doing a framework is established to assess tasks in the RIBA Stages of work and critique how automatable designers are.

Definition:

Automation Readiness Level (ARL) :

The rating system for the readiness of a task to be automated.

Recognising the need for a rating scale that addresses the tasks in a design project, the author established the automation readiness levels (ARL's). They are a combination of technology readiness levels and variables that determine computerisation. The ARL's provide a series of checkpoints that determine how susceptible a task in the design process is to automisation. Maintaining the same numbering structure as TRL's[33] and using the variables established by Frey and Osborne *(figure 8)*, the automation readiness levels (ARL's) are organised from 1-9. 1 being a low readiness or a low probability of automisation and 9 being a high readiness or a high probability of automisation.

The readiness levels presented can be used as an overall schematic evaluation for designers to assess the stages of the design process, in regards to their computerisation. When a task is rated ARL 1 or 2, it entails a significant proportion of social knowledge and perception. ARL's 3 and 4 occur when project information is organised and designed requiring creative knowledge, with ARL 5 occurring at data issue. As data is transferred and parameter led design occurs the level reaches ARL's 6 and 7. When tasks become most repetitive, they reach levels 8 and 9.

[33] Referred to are the technology readiness levels, the structure of the ARL's mirrors that of NASA's in the most ready tasks to computerisation at the top of the checklist. Each RIBA stage can be evaluated by the tasks it entails at each stage of the ARL's.

NASA, 2012. **Technology Readiness Levels.** Available online at: https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html

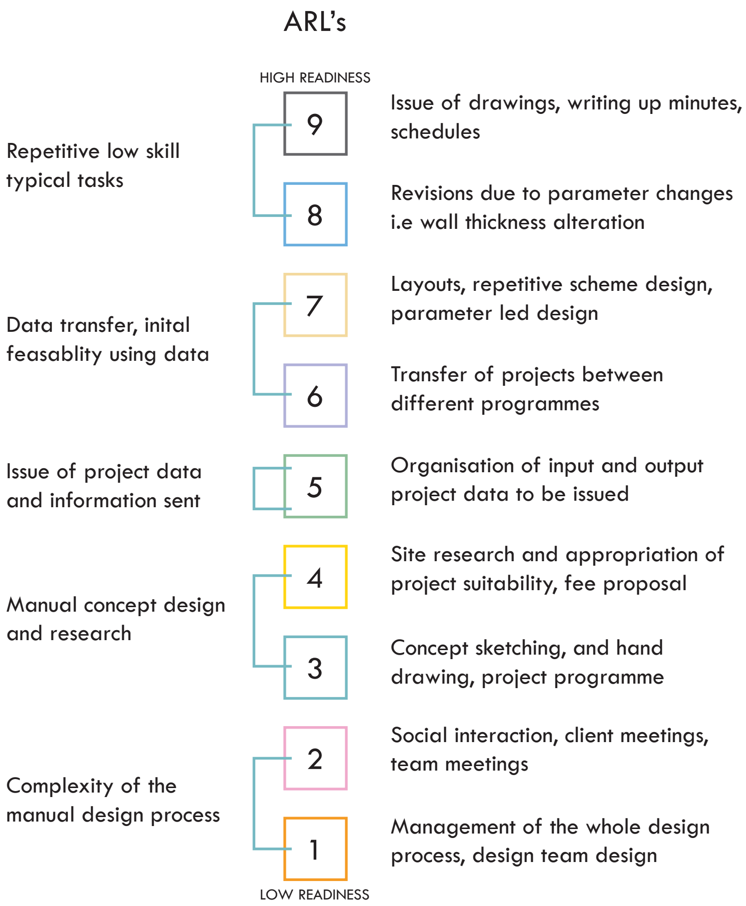


Figure 8. Automation Readiness Levels

1.4
APPLICATION TO THE RIBA STAGES OF WORK

Section 1.4 applies the ARL rating scale to each stage of the RIBA Plan of Work. Using information from the interview timelines, it provides an overview of the tasks in each stage, followed by a rating of automatability. In doing so, it aims to demonstrate which stages have the most automatable behaviour.

Stage 0 – Strategic Definition 1

The tasks at Stage 0 entail some of the highest amounts of social intelligence and perception, at this point, the main tasks are to establish the project programme and understand the business case or brief of the client.[34] Discussions with the client regarding the aims for the project and reviewing precedents or other projects are essential at this stage.[35] If we use the variables of social intelligence, creativity and perception and manipulation established by Frey and Osborne[36] (2013) to rate this stage on its readiness for automation it is at ARL 1 – Complexity of the manual design process.

Stage 1 – Preparation and Brief 3 6

At Stage 1 the core objectives are to develop the project objectives and scope. At this point, there is still a significant amount of unpredictability within the tasks. The project scope will vary for each project, and the initial feasibility studies will require site-specific research. It is here a client with a lot of site data will issue it to the design team, the organising tasks of which are seen as more repetitive. Here, we begin to see the effects of data on the project stages as information recieved early can influence design decisions that would usually happen later in the project. For example, in the conversation with Lauren Poon[37] she refers to how early known data on something such as wall thickness influences the construction. Assessing this stage using the previous variables shows that certain parts of this stage have a higher automation readiness level than others with a combined ARL of 3 and 6.

[34] Individual RIBA stage information compiled using data collected via interviews with architects. See appendix 1.

[35] Task detail at each stage cross referenced with RIBA plan of work. Available online at: [https://www.ribaplanofwork.com/]

[36] Frey, C & Obsorne, M. 2013. The Future of Employment: How Susceptible are jobs to computerisation? University of Oxford.

[37] Refers to interview with Lauren Poon, CallisonRTKL, transcript found in Appendix 3.0

Stage 2 – Concept Design | 4 | 7

The primary task at Stage 2 is to prepare the concept design, including the outline proposals for all developed design strategies and issue a final project brief. If we refer to the variables of social intelligence, creativity and perception and manipulation set by Frey and Osborne[38] (2013) this stage has a variation of both predictability with parameter led design and creativity. Even a client with standardised site data (views, sun path, and standard typology) can provide design parameters that can be understood by a computer script. Companies such as Publica will spend a long time on site, understanding the space rather than downloading data[39]. There is also the aspect of concept design sketching and form generation which can be primarily seen as a human-orientated exercise. As there is both a combination of initial feasibility using data and manual concept design this stage has a combined ARL of 4 and 7.

Stage 3 – Developed Design | 1 | 2 | 5

Stage 3 - Developed design begins to see a coordinated proposal for areas and structural and building services systems. This means it requires an increased amount of overall design management, planning permission is also usually submitted at this stage. The complexity of the manual design project is combined with the data input and output of measured variables. There are tasks at this point of the project that begin to touch upon several ARL's. The transition of data is a repetitive task that is different for each project, but it can be transitioned into a set of computer instructions. In contrast, the client meetings and coordination within the design team requires perception and social intelligence, alongside the level of creativity needed to design successful architectural spaces. This stage has a combined ARL of 1, 2 and 5.

[38] Frey, C & Obsorne, M. 2013. The Future of Employment: How Susceptible are jobs to computerisation? University of Oxford.

[39] Refers to interview with William Beeston, Publica transcript found in Appendix 5.0

Stage 4 – Technical Design

2 5 6 8

The core objectives of Stage 4 - Technical design is to prepare documents with all relevant specialists, sub-contractors, and services consultants. At this stage the tender documents are being prepared and there is a high amount of collaboration, especially on a large project. Data from different models and programmes will be transferred through to others at this stage to enable the highest model efficiency. If the design is parametric, data rich revisions in the structural elements can be changed at one point in the system and in turn have effects on the rest of the design.[40] This removes the need for multiple revisions to large sets of physical drawings and also introduces another set of instructions that can be read by a computer. This stage has both social complexity in regards to client meetings but also a significant amount of data allowing for the introduction of computational design. Stage 4 has a combined ARL rating of 2, 5, 6 and 8.

Stage 5 – Construction

2 5

The level of involvement at the construction phase is defined by the type of procurement route taken at the earlier stage of the project. This stage is primarily dominated by the contractor and construction team. The design team will attend regular site meetings as the project progresses. During the interview with Jeff Kahane, he highlighted how technology allows architects to add complexity without cost. 'That point of being able to send drawings to a fabricator and being able to do complexity at no extra cost is wonderful.'[41] Data will flow between models and the output information relayed to the rest of the team. If we use the variables of social intelligence, creativity and perception and manipulation[42] set by Frey and Osborne (2013) to rate this stage on its readiness for automation it is at ARL's 2 and 5.

[40] Individual RIBA stage information compiled using data collected via interviews with architects. See interview in appendix.

[41] Kahane, J. Appendix 4.0

[42] Frey, C & Obsorne, M. 2013.

Stage 6 – Handover and Close Out 1 2

The project team's priorities during this stage will be facilitating the successful handover of the building in line with the project programme. In the period immediately following is the concluding of all aspects of the building contract. This includes the inspection of defects as they are rectified or the production of certification required by the contract.[43] Stage 6 stage requires an overseeing of the project tasks, site and client meetings with a high level of complexity within the manual design process. Evaluated with the variables of social intelligence and perception it is rated with an ARL of combined 1 and 2.

Stage 7 – In Use 2 6

Upon completion there is the defect liability period, this is 3 months on small projects, 6 months on larger and 12 months on some. During this period the design team returns to the project to see how it is performing. This can sometimes be to check the sustainability claims of products such as LED lighting that come with lifespans and other claims of efficiency. There are also architects such as Jeff Kahane who will return to photograph the finished architecture[44]. This stage is primarily about maintaining a relationship with the client and attending any relevant meetings. However, recently the large data sets that exist once a building is in use means that there is an aspect of this stage that is automatable. For this reason Stage 7 is rated with a combined ARL of 2 and 6.

[43] Task detail at each stage cross referenced with RIBA plan of work. Available online at: [https://www.ribaplanofwork.com/]

[44] Refers to interview with Jeff Kahane, Jeff Kahane Associates, transcript found in Appendix 4.0

1.5
EVALUATING THE CHOSEN TASK

Chosen Stage:

RIBA Stage 2 - Concept Design

Section 1.5 takes findings from the interviews and the ARL rating scale to make a choice into what task the thesis will aim to automate. Using the ARL's this section rates all the tasks in RIBA Stage 2 on the timeline figure 10. This section chose RIBA Stage 2 due to its combination of repetitive tasks and tasks requiring high manual creativity and intelligence. By deconstructing, this stage, section 1.5 provides a framework to establish what particular task will section 2 will develop into a computer script.

The chosen scope for the next section in this thesis will be RIBA Stage 2 – Concept design. During this stage there is a combination of tasks with social and creative intelligence and tasks such as room layouts or area allocation that can be broken into a set of numerical rules.

In order to evaluate the automatabiltiy of RIBA Stage 2 in detail, the automation readiness levels will be applied to every task that occurs at this stage. Some of the information will be particular to Stage 2 and some will be transferable and occur during other stages of the design process. It is de-constructed in *figure 10* using data from the previous interviews, creating a timeline of tasks that are evaluated according to the ARL's.

The development of software in architectural design has provided designers with a new tool kit for developing their projects. Manovich (2014) discusses the ability of software being able represent most media whilst augmenting them with unique properties and its ability to be 'active' and respond to live queries.[45] Whilst the level of manual dexterity required to physically draw internal building layouts is high, it is a task that can has already seen transition into CAD. With developments in technology it can be driven by data such as internal areas, building orientation, amount of circulation required and other data readily available from a client once a brief is established. This section aims to rate the tasks at Stage 2 in order to develop an understanding of which ones can be further augmented with automation.

[45] Discussing the unique properties of the metamedium Manovich describes it as being able to "serve as "a programming and problem solving tool," and "an interactive memory for the storage and manipulation of data." Manovich, L. (2014). **Software Takes Command.** New York, Bloomsbury, p.68

‘I always take the view that usually when technological developments are made, it is just another tool in your toolbox and a carpenter doesn’t throw away the ordinary screw driver because he has one he can fit onto his drill.’[46]

The interview data gathered both conflicted and backed up assumptions made to the automatability of tasks at RIBA Stage 2. For example, during the conversation with Jeff Kahane he noted that he couldn’t think of ways automation could infiltrate at an early stage. To which he says ‘I can’t think of anything right at the beginning, its more to do with juggling orientation and loss of daylight or views and parking, privacy etc.’[47] However, this was immediately contradicted during the conversation with Lauren Poon in which she suggests data can be used to optimise the use of a site to get the most value for the client.

Plan of Work *2013*	2. Concept Design
Core Objectives	Prepare Concept Design, including outline proposals for structural design, building services systems, outline specifications and preliminary **Cost Information** along with relevant **Project Strategies** in accordance with **Design Programme**. Agree alterations to brief and issue **Final Project Brief**.
Procurement	The procurement strategy does not fundamentally alter the progression of the design or the level of detail prepared at a given stage. However, **Information Exchanges** will vary depending on the selected procurement route and **Building Contract**. A bespoke RIBA Plan of Work 2013 will set out the specific tendering and procurement activities that will occur at each stage in relation to the chosen procurement route.
Programme	Review **Project Programme**.
(Town) Planning	Planning applications are typically made using the Stage 3 output. A bespoke RIBA Plan of Work 2013 will identify when the planning application is to be made.
Suggested Key Support Tasks	Prepare **Sustainability Strategy**, **Maintenance and Operational Strategy** and review **Handover Strategy** and **Risk Assessments**. Undertake third party consultations as required and any **Research and Development** aspects. Review and update **Project Execution Plan**. Consider **Construction Strategy**, including offsite fabrication, and develop **Health and Safety Strategy**.
Sustainability Checkpoints	Confirm that formal sustainability pre-assessment and identification of key areas of design focus have been undertaken and that any deviation from the **Sustainability Aspirations** has been reported and agreed. Has the initial Building Regulations Part L assessment been carried out? Have ‘plain English’ descriptions of internal environmental conditions and seasonal control strategies and systems been prepared? Has the environmental impact of key materials and the **Construction Strategy** been checked? Has resilience to future changes in climate been considered?
Information Exchanges (at stage completion)	Concept Design including outline structural and building services design, associated **Project Strategies**, preliminary **Cost Information** and **Final Project Brief**.
UK Government Information Exchanges	Required.

Figure 9. Stage 2 tasks as defined by the RIBA Plan of Work 2013

[46] Quote taken from an interview with **Jeff Kahane** responding to a question on what he thinks could be automated. ‘The number of tools simply increases and you have more tools at your disposal, and whilst some things with technology replace others but I quite like working with physical models and cad models with renders and without.’ - Appendix 4.0

[47] Quote taken from an interview with **Jeff Kahane** - Appendix 4.0

Furthermore, she adds that computational design could split architecture two ways 'for architects who are focused on designing a fixed thing like an object it's going to be more about crafting and then at the other end of the scale with automation and systems design will be the establishment of a series of relationships.'[48] This supports the split rating of this stage, as some tasks will be data driven whilst others will be intuitively carried out with skill and social knowledge.

Continuing to reinforce the decision of the ARL rating 4 & 7 is the conversation with William Beeston on the importance of understanding space. Whilst explaining the role Publica takes in writing a client's brief for the public realm, he refers to what he thinks the future of architecture could include. Saying 'I think it should be more about designing spaces and I don't think many people get that, the nuance of space, in particular public spaces.'[49] Again, this point of architects better understanding the importance of space and the built environment was highlighted in the interview with Alastair Parvin when he says 'if architects got really, and I think they will have to be, serious about user experience in the built environment they would survive a lot longer.'[50]

'The built environment is a product of human activity and creativity, all kind of human behaviour and desire is tied into it.[51]

The following sections will focus on one particular task at RIBA Stage 2, this will be the initial layout of rooms within a building envelope. Using data and components in Grasshopper and Rhino 3D this thesis will test if a computer can carry out a design task. This choice is made to provide an insight into how a certain level of creativity can be produced by a computational algorithm and also serves to provide crucial knowledge on how architects may need to re-skill themselves to remain current in a digitally driven environment.

[48] Quote taken from interview with **Lauren Poon** - Appendix 3.0

[49] Quote taken from interview with **William Beeston** - Appendix 5.0

[50] Quote taken from interview with **Alastair Parvin** - Appendix 1.0

[51] Quote taken from interview with **William Beeston** - Appendix 5.0

THE ARL'S AND RIBA STAGE 2

APPLYING THE ARL'S

The next step is to apply the ARL's to all of the interview feedback gathered about the tasks in RIBA Stage 2.

RIBA STAGE 2

TIMELINE

THE TASKS OF STAGE 2

This timeline combines the data gathered in the individual interviews about the tasks undertaken at RIBA Stage 2.

They are rated using the Automation Readiness Levels.

Figure 10

RIBA STAGE 2

De-constructing the tasks of RIBA Stage 2 of the Plan of Work assigning Automation Readiness Levels (ARL's) to each task.

Figure 8

2

Concept Design

4

Site Visit 1,2

Site visit/ photographs/ review of space

Mapping

Overay the data on to maps of the site with indesign

5

4

Site Visit 3

Site visit/ photographs/ review of space

3

3D Models & Sketches

Card and foam models of concept design proposals/ sketches of possible scheme and layouts.

Site Visit 4

Site visit/ photographs/ review of space.
Look for existing data on the site. i.e TFL gate recording

7

3

Computer Visuals

Sketchup visuals of the scheme early on for the client to see development

Site Visit 6

Different nuances of the site are highlighted e.g. focuses on the active frontages etc

2

5

Mapping

Overlay the data on to maps of the site with indesign

Site Visits

There is a strong importance to visit the space often and understand its properties socially within the built environment

2

2

Site Visit 5

Understanding how people use the space

5

Site Visit 7

Site visit/ photographs/ review of space

5

Mapping

Overlay the data on to maps of the site with indesign

6

SpaceSyntax

The inclusion of data from SpaceSyntax to give the client solid data

Precedent

Precedents of both designs that work well and designs that dont work well in similar public spaces are gathered for the client

4

2 3 4

Brief

Once the surveys are completed the client recieves a solid set of surveys/ work/ brief to enable them to address the public realm within their project

Design Analysis Using Software

Maximising views to certain landmarks or lighting strategies using software to make the best design decisions.

7

6

Pattern Design & Evolution

Knowledge of design patterns previously contained in books and developed in ages can be input into script.

Computational Design

Setting up a computational solver to work with a mass or a site and respond to design problems to give the most value.

6

7

Initial Design

Building layouts are drawn according to the clients brief.

DEVELOPING THE DEFINITION

THE GRASSHOPPER SCRIPT

The next chapters of this thesis begin by describing the process of writing an evolutionary script.

Following this there is an evaluation of the results and a discussion surrounding the implications of automation on the architecture profession.

PART 2 - SCRIPTING

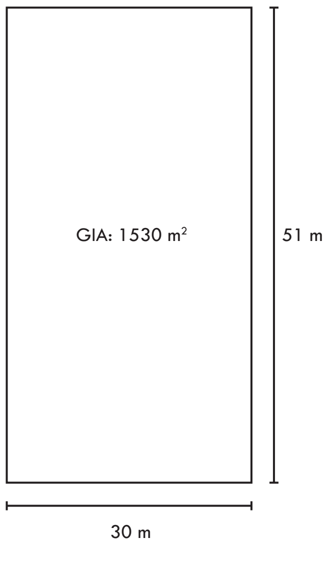
2.1
DATA INPUT AND BRIEF

Part 2 will test if room layouts can be automated using the architectural scripting tool Grasshopper. The first step is to define what the algorithm will be aiming to automate. This is done by defining a set of numerical inputs which signify the building envelope, the number of desired rooms and their areas. Following will be the writing of an algorithm. The results will then be recorded from the Rhino 3D model space and critiqued regarding their successfulness.

Algorithmic design in architecture begins in the same way that any design project would, in establishing the design constraints and desired outcome. In this sense the design goal is to produce computer generated room layout within a building envelope.

The desired envelope (external walls) and areas (internal rooms) are established prior to the scripting. This task will aim to use the visual scripting tool Grasshopper to generate room layouts that best fit the defined constraints. The benefit of using system design through Grasshopper is that if the desired rooms and building envelope change, the algorithm can encorporate this to produce a different result.

The first set of constraints relate to the dimensions of the chosen footprint and are outlined below. *(Figure 11)*



0. BUILDING ENVELOPE

1. DESIGN CONTROLS

Rooms : 3 Bedrooms
1 Bathroom

Circulation : 1 Landing
1 Corridor
1 Staircase

TOTAL: 7 Areas with Variable sizes

+ for identification only not to scale

Figure 11. Design controls established as a brief or goal for the script. In this case a building envelope is established and a series of internal rooms with variable areas are decided.

The second set of constraints relate to the internal proportions of the layout and are outlined below. These are the internal areas for the desired spaces within a building envelope. *(Figure 12)*

2. INTERNAL ROOMS TOTAL: 7 Areas with Variable sizes

Room 1	**Room 3**	**Staircase**	**Circulation**
Desired Area: 439.2 m^2	Desired Area: 219.57 m^2	Desired Area: 100.29 m^2	Desired Area: 149.68 m^2
Room 2	**Bathroom**	**Landing**	
Desired Area: 350.35 m^2	Desired Area: 177.63 m^2	Desired Area: 93.28 m^2	

By aiming to automate room layouts this section takes a task from RIBA Stage 2 that had a high ARL rating which would be developed with data provided by the client. It is written to test if two variables; building envelope and area size, can be specified in an algorithm and generated by Grasshopper which is an architectural tool. This task of data driven spatial design was previously given an ARL of 7 as it has been broken down above in to a series of numbers and parameters.

Figure 12. Layout controls to input into the script in relation to the design control. These are numerical values of desired areas for the internal rooms of the building layout.

2.2

WRITING THE SCRIPT

Section 2.2 consists of the Grasshopper script written to generate the room layouts. It breaks the script down into the individual components and describes their purpose. A script in Grasshopper is referred to as a definition as it defines a series of commands and geometry in the user interface. The visual scripting program Grasshopper is part of the standard Rhino 6.0 toolset and is a design tool widely used in architecture.

This chapter will focus on the writing of a Grasshopper script with an evolutionary problem solver component 'Galapagos'[52]. The desired outcome of this task is to produce a series of computer generated interal building layouts. This is done by writing an algorithm for the initial building geometry and providing the evolutionary solver a series of desired areas for spaces. In doing so it will test if a task completed by an architect at RIBA Stage 2 can be automated in a computer.

Generative design within architecture is by no means a new topic, its benefit being the production of parameter driven and optimized results with multiple possible outcomes rather than one final product. The topics of machine learning, optimisation and technological innovation are simply some of those undertaken by the applied research UCL laboratory 'Space-Syntax'[53]. The material in this section addresses a topic often approached within a PhD timeframe. Therefore, addressing it within the scope of a thesis requires a streamlined approach focusing on one variable. The final chapter of this section will analyse the nature and effectiveness of the components used, opening a discussion on computerisation within design.

'The term "Evolutionary Computing" may very well be widely known at this point in time, but they are still very much a programmer's tool. It is my hope that Galapagos will provide a generic platform for the application of Evolutionary Algorithms to be used on a wide variety of problems by non-programmers' (Rutten 2010)[54]

[52] Galapagos is a component inside of grasshopper that can optimize a shape so that it best achieves a user defined goal. For this to work, Galapagos needs a series of options or genes to try out, and a defined goal or fitness value. Aweida, 2011.

[53] University College London, The Bartlett. Research. **Space Syntax Laboratory.** Available online at: [https://www.ucl.ac.uk/bartlett/architecture/research/space-syntax-laboratory/]

[54] Grasshopper developer David Rutten opening his blog post following the AA lecture Computing Architectural Concepts. The post deals with evolutionary solvers in general but uses Rhino, Grasshopper and Galapagos to demonstrate the topics. Rutten, D. 2010. **Evolutionary Principles applied to Problem Solving.** Available online at: [http://www.grasshopper3d.com/profiles/blogs/evolutionary-principles] Accessed 25/03/2018

Utilising an evolutionary problem solver allows a designer to input a series of variables or 'genes'[55] within the model state that when combined together produce an output that can be measured in terms of its 'fitness'. The first step to writing the definition is to generate a series of points that can be manipulated and controlled by the solver. *Figure 13* below shows the list of variables that define the location of a set of points in the Rhino interface. The sliders allow the Galapagos component to move them in order to find its solution. These sliders will then determine the number of rooms in the final layout. The numbers 0-6 in one set correspond to the other set and each set of slider points is the edge or wall of one room in the model.

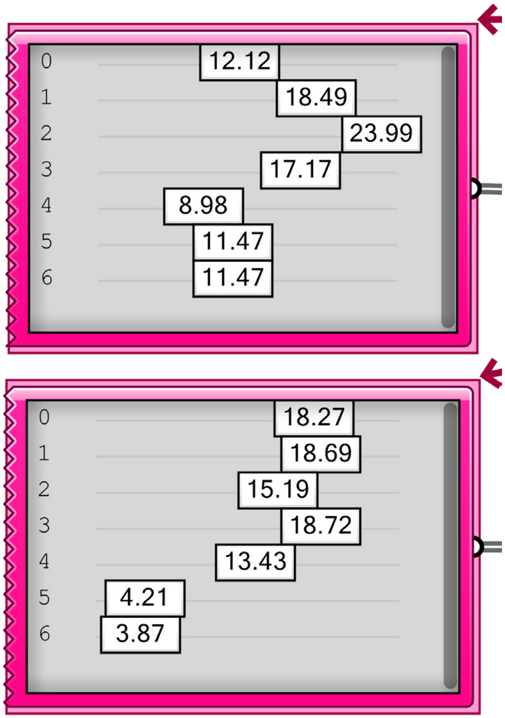


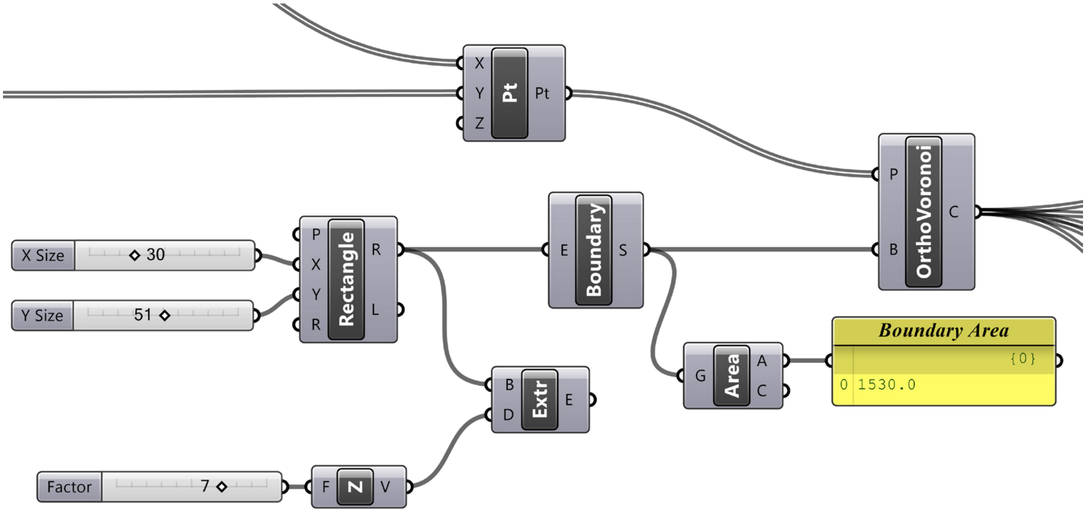
Figure 13. Gene pool list – variable sliders in Grasshopper interface.

[55] Grasshopper Component Index, Params > Util > Gene Pool. Available online at: http://rhino.github.io/components/params/genePool.html

Just as a building envelope is crucial to the containment of a design, the second step to building an effective algorithm solution is to establish a rectangle within which the points are bound[55]. The rectangle signifies the exterior walls of the building envelope in which the desired layout will be generated. Within this script the rectangle was created in Grasshopper and not Rhino, its benefit being that the size can be changed dependent on the brief requirements and all its connections or transformations following can change accordingly. *Figure 14* below demonstrates this creation with an extrusion that allows the visual interface to display 'wall' type elements.

Panel components in Grasshopper allow the user to display custom notes and text values, they also allow the user to view the current status or value of another component.[56] The yellow panel in *figure 15* displays the boundary area of the rectangle enabling an efficient work flow through the scripting process and accurate calculations for the next steps of the algorithm. The boundary area is the building envelope size.

Figure 14. Rectangle boundary creation and voronoi division of space.



In Grasshopper, the next component of the algorithm is the division of space dependent on the number of specified points in the gene lists. The slider points both correspond to edges of the space and by

[55] It is also worth noting that the organization of the definition is crucial to understanding how to use Galapagos. For now, we will assume that the definitions to be used with Galapagos will be organized in three general groups. 1: Input Parameters - the components that control the geometry modelled in Rhino. 2: Geometry - the only part of the definition that actually draws something in Rhino. 3: Fitness Equation - components that solve a particular equation based on your geometry resulting in a single number component that is connected to the Fitness input on Galapagos. Raznick, D. 2012. Evolutionary Computing with GH and Galapagos. Available online at: [https://sites.google.com/a/umn.edu/digitalresources/tutorials/evolutionary-computing-with-gh-and-galapagos]

defining points for sliders 0-6 there are 7 spaces generated. This script utilises a Grasshopper user special component 'OrthoVoronoi'[57], which generates a voronoi pattern constrained to angles of only 90°. Voronoi is the division of a plane by a series of points. This component is used as it allows for the control of its internal area, enabling the designer to specify the number of rooms it is divided into and their size.

The next set of components define the fitness equation for the Galapagos solver[58], they will solve a particular equation based upon the connected voronoi geometry, in this case the size of the rooms. This section of the script uses Grasshopper's mathematical equation functions to control the gross desired area and the amount it deviates from this. The gross desired area is the building envelope size. Due to Galapagos being an evolutionary solver we cannot simply give it one set of parameters, it requires a series of variables to optimize. The fitness is the sum of all the deviations of room sizes, which is all of their possible sizes within the building envelope. Galapagos will aim to minimise the area deviations and produce a result as close to the optimal parameters or desired room sizes.

Again the yellow panel component is used to display information from the script at different stages.

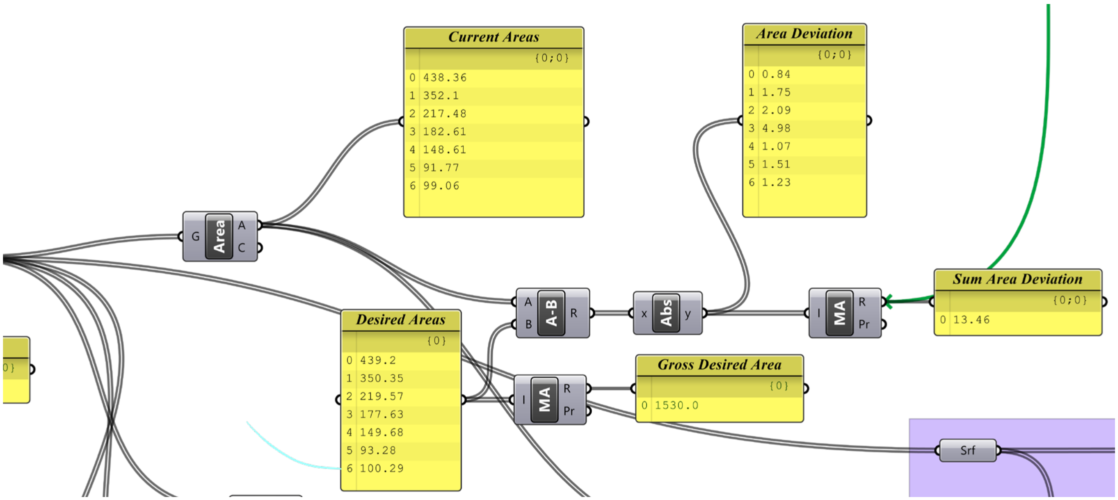


Figure 15. Equation linked to previous geometry and Galapagos fitness solver.

[56] Grasshopper Component Index, Params > Input > Panel. Available online at: http://rhino.github.io/components/params/panel.html

[57] Harding, J. 2014. OrthoVoronoi. Grasshopper Discussions. Available online at: 'http://www.grasshopper3d.com/forum/topics/orthovoronoi Accessed 25/03/2018

[58] The fitness number is a value that you tell Galapagos to try and solve towards. In this case the number is a series of room areas that the designer wishes in the building envelope. This number of rooms is specified in Grasshopper. The points in the gene sliders are the areas of the individual rooms and their area, set out in the design brief, is input in the desired areas panel.

As architects, we understand the value of easily readable visual data output. One of the components within Grasshopper that allows for this is the 3D Text Tag[59]. It represents a list of 3D text tags in a Rhino viewport, enabling the user to connect it to a series of numerical data which becomes a visual output on the Rhino interface. Here it is used to display the room areas or room numbers.

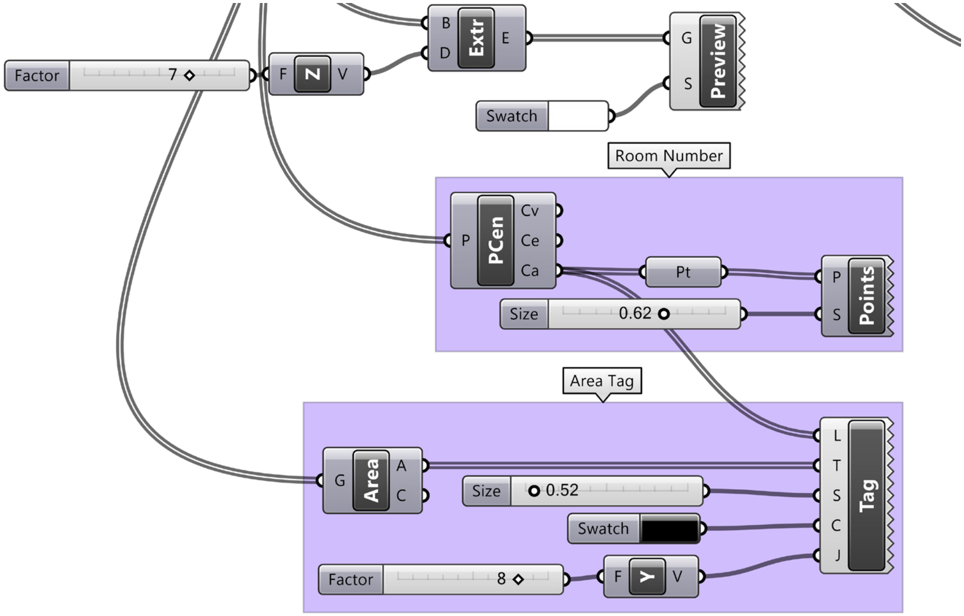


Figure 16. Script labelling either the centre point of a space giving a room number or the numerical data of the area size.

Further to this, another benefit of the visual scripting library in Grasshopper is the gradient[60] component, when connected to geometry represents a multiple colour gradient. The deconstruct domain[61] component splits the list of areas into two parts and divides the gradient accordingly. This section of the definition uses both components to create a colour gradient randomised based on the area sizes of the spaces. This enables the user to better see the visual result in the Rhino interface when running the Galapagos solver.

[59] Grasshopper Component Index, Display > Dimensions > Text Tag 3D. Available online at: https://rhino.github.io/components/display/textTag3D.html

[60] Grasshopper Component Index, Params > Input > Gradient. Available online at: https://rhino.github.io/components/params/gradient.html

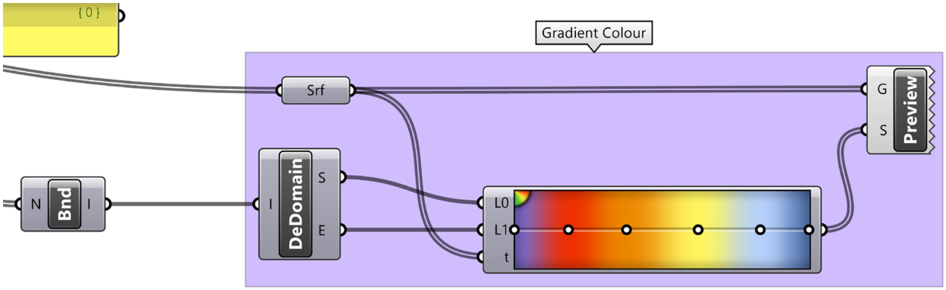
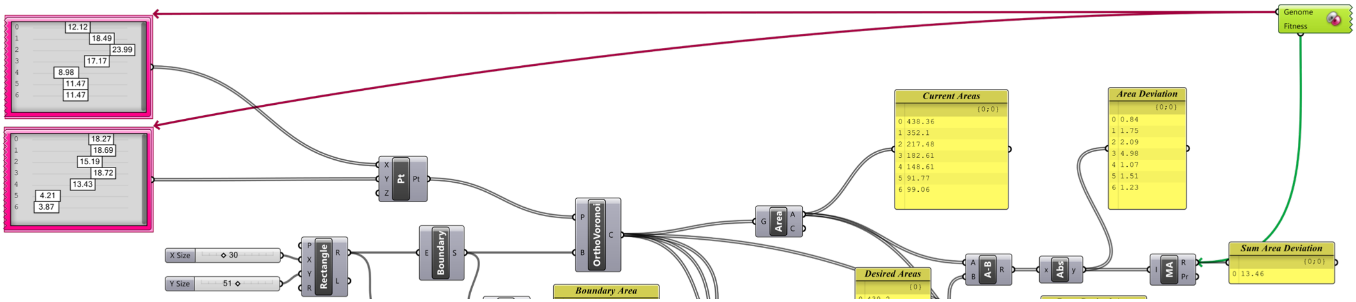


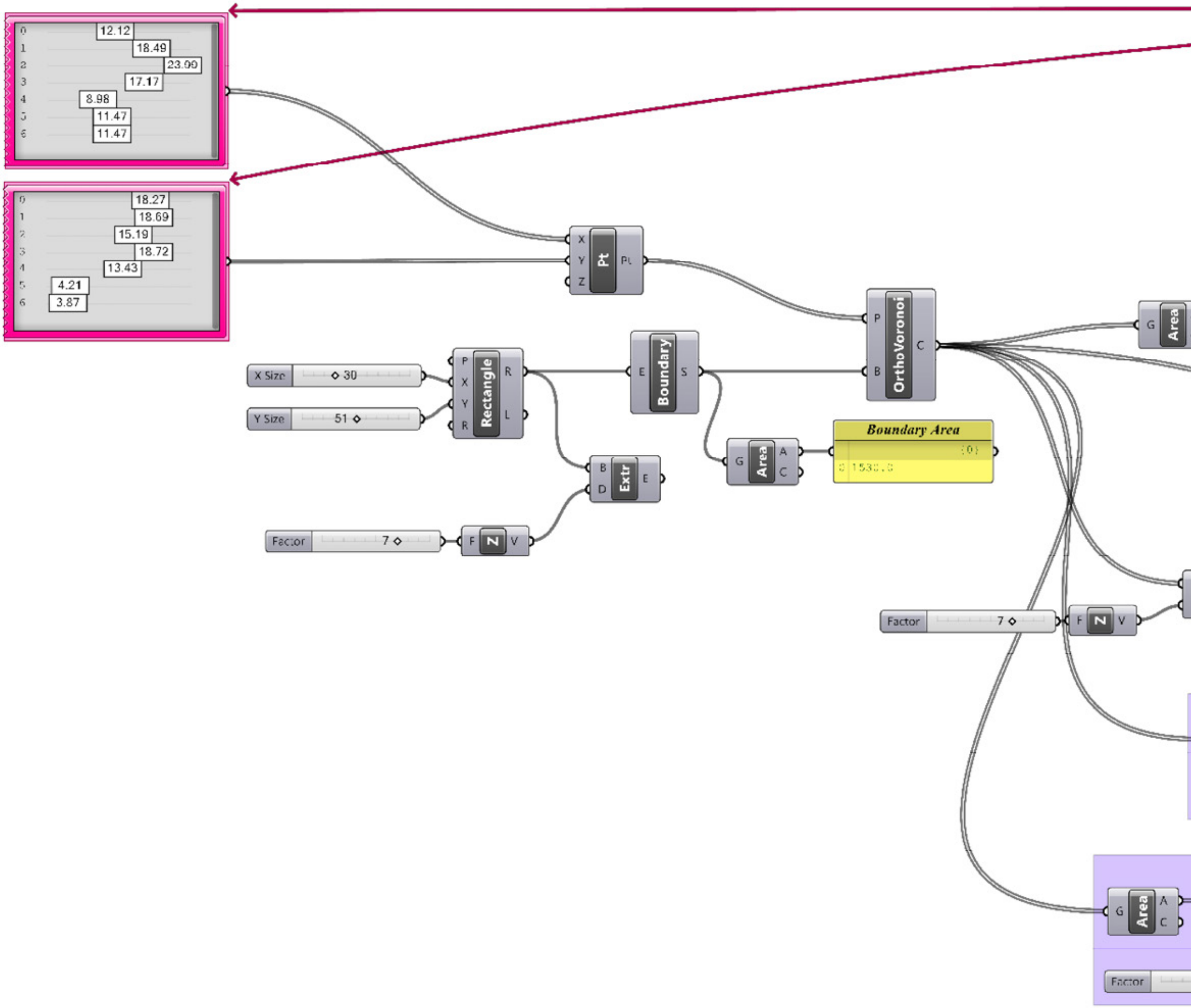
Figure 17. Gradient affecting the colour of rooms dependent on their area size.

The final step to the definition is to connect the Galapagos genome variables and fitness calculation established above. The connections are linked from the Galapagos component to the definition. Unlike other components in Grasshopper which link from the component to component, it does not receive any connections as it is optimizing the geometry not creating or transforming it. Once connected the user double clicks the Galapagos component to open the solver, in this window the fitness setting must be at minimize as the aim is to minimize the deviation between the desired area and the actual area achieved. *Figure 18* below demonstrates the pink and green connections to the definition.

Figure 18. Galapagos component connected to variables and fitness parameters.



[61] Grasshopper Component Index, Maths > Domain > DeconstructDomain. Available online at: https://rhino.github.io/components/maths/deconstructDomain.html


12.12
18.49
23.99
17.17
8.98
11.47
11.47
18.27
18.69
15.19
18.72
13.43
4.21
3.87
Pt
OrthoVoronoi
Area
X Size
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Y Size
51
Rectangle
Boundary
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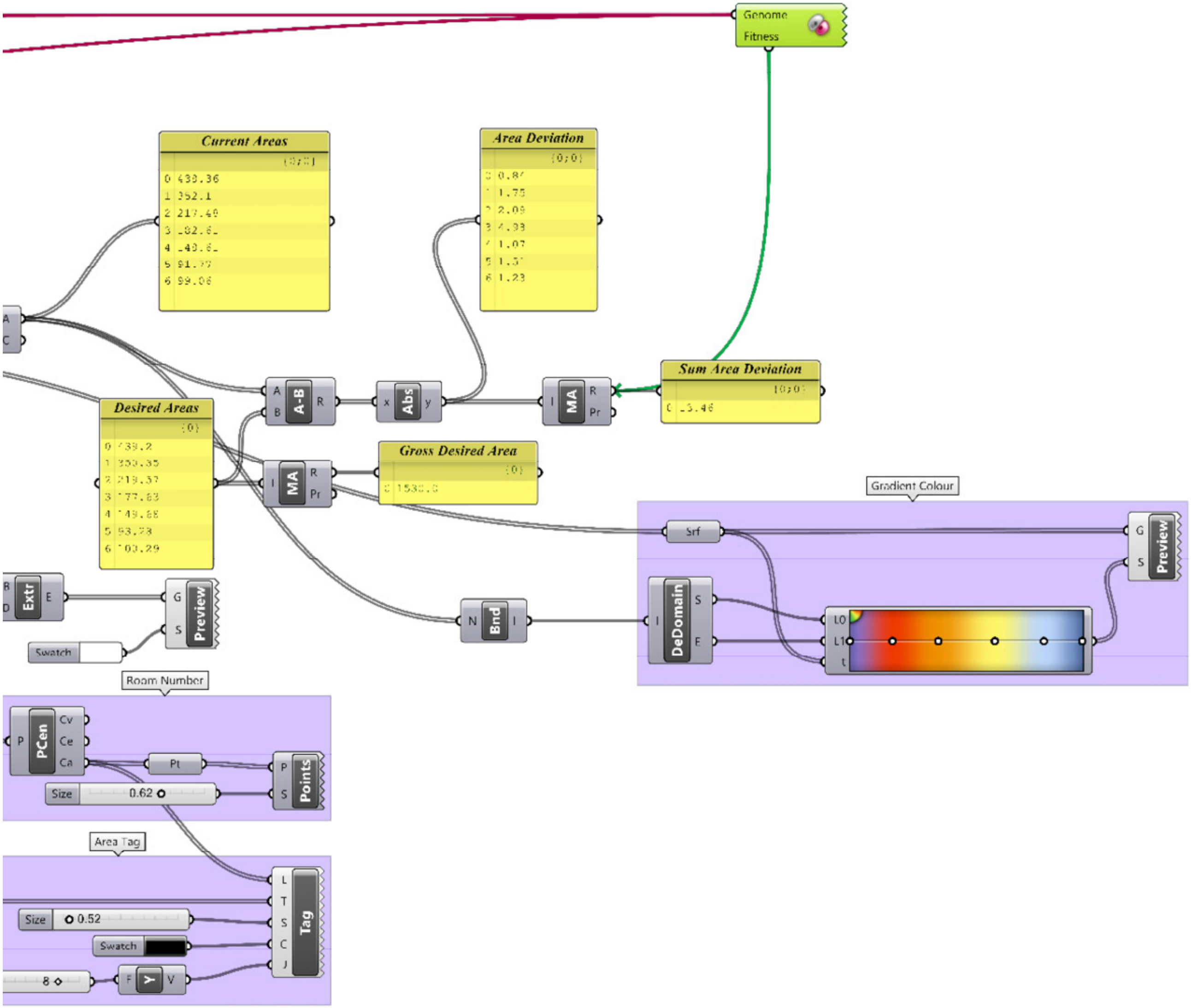

Genome
Fitness
Current Areas
Area Deviation
Sum Area Deviation
Desired Areas
Gross Desired Area
Gradient Colour
Room Number
Area Tag
Swatch
Size
Srf
Pt

2.3

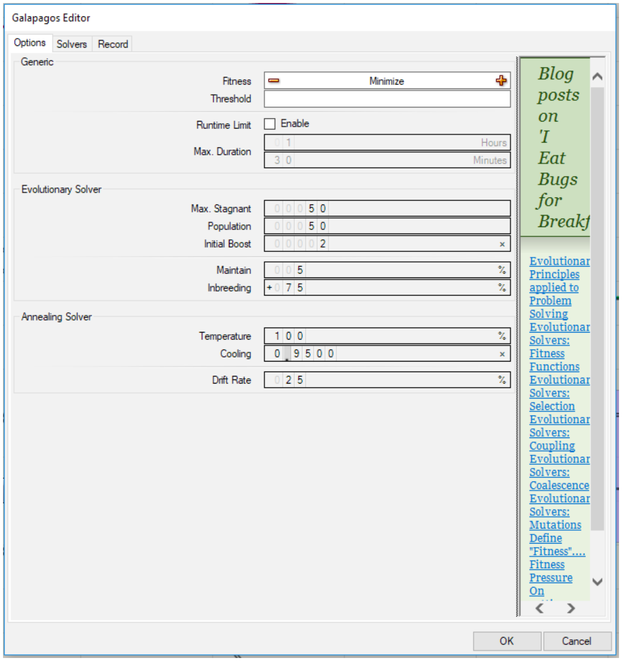
THE EVOLUTIONARY PROBLEM SOLVER

Section 2.3 breaks down the use of an evolutionary problem-solving component used in the Grasshopper script. The component Galapagos will solve a problem using numerical inputs by the designer. In this script, Galapagos is aiming to produce a series of room layouts that match the design brief in the previous section.

'Evolutionary problem solving mimics the theory of evolution employing the same trial-and-error methods that nature uses in order to arrive at an optimized result. When automated for specific parameters and results, this technique becomes an effective way to computationally drive controlled results within the iterative design process – allowing designers to produce optimized parameters resulting in a form, graphic or piece of data that best meets design criteria.'(Aweida, 2011)[62]

The first step to computing the solution is opening the Galapagos solver component, double clicking this in the Grasshopper interface opens the options menu in *figure 20*. The fitness toggle is set to minimize as we are minimising the deviations between actual and desired areas. The second tab is the 'solvers' menu which opens as *figure 21*, this is empty upon opening but will display the fitness and genome information as it computes them.

[62] Aweida, 2011. E**volutionary Form Finding with Grasshopper + Galapagos.** Yazdani Studio Research. Available online at: [https://yazdanistudioresearch.wordpress.com/2011/08/04/evolutionary-form-finding-with-grasshopper-galapagoes/]



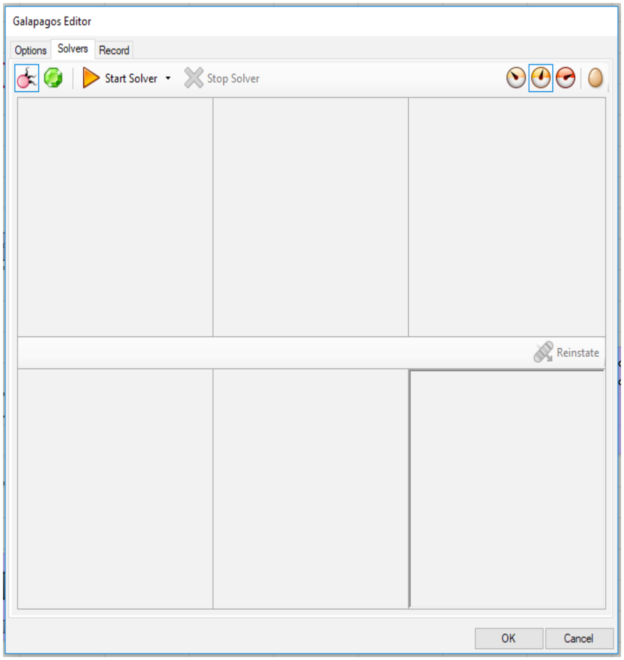


Figure 20. Galapagos options interface upon initial opening.

Figure 21. Galapagos solver interface upon initial opening.

As Galapagos runs it is working to pair the best possible genes together to reach the highest level of fitness. In his blog posts surrounding the use of the component its creator, David Rutten, explains its principles in relation to biological evolution[63]. The solver works to find the best genome within the possible selections and pair with the closest individual in the genome map. In this script one genome is the creation of one internal layout. An example of this can be seen in *figure 22,* the genome map is represented as a series of dots on a grid. Once the genome has been selected the solver produces an 'offspring' that is a result of these 2 individuals and the process repeats until the Galapagos has found the closest solution or the solver is manually stopped by the architect[63]. In this script the best possbile outcome would be matching room areas for the input of brief requirements and the script output. Once it finds a layout that is close to its desired solution it will continue to develop that layout to reach its goal.

Figure 22. Galapagos solver window stopped at 200 evolutions.

[63] There is minimal published documentation on Galapagos, in the comments of this forum post the creator of the component David Rutten explains the basic principles of how it works. Rutten, D. 2010. References about Galapagos? Available online at: [http://www.grasshopper3d.com/forum/topics/references-about-galapagos]

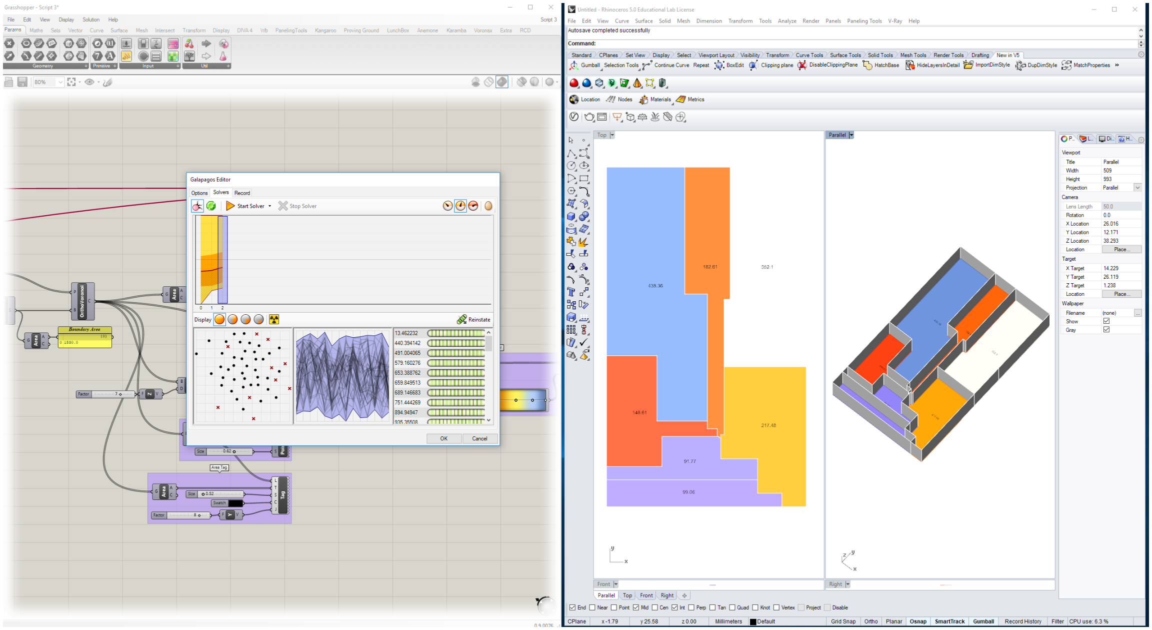


Figure 23. Galapagos solver running in grasshopper with the Rhino interface output.

2.4

EVALUATION OF GRASSHOPPER FINDINGS

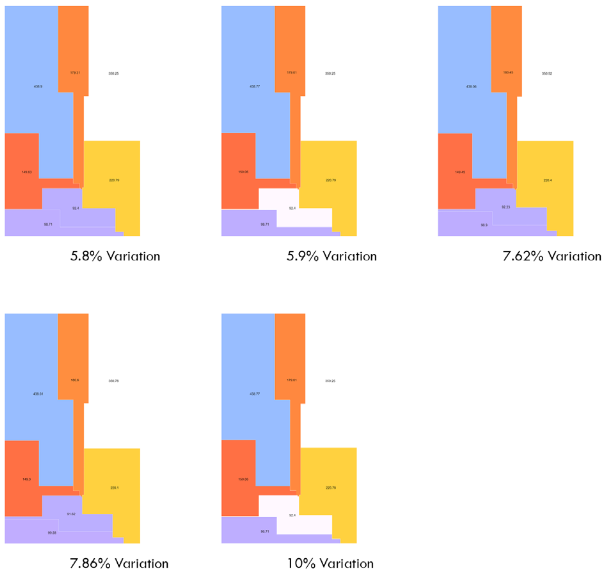
90% ACCURATE LAYOUTS

These are the layouts produced by Galapagos that are the top 10% in relation to the variation between the designers area inputs and the scripts output.

The Galapagos solver shows the user the top percentages of genome solutions in the solver window in order of their accuracy. One genome is representative of one internal layout solution in the Rhino 3D space. There is then the ability to reinstate any of these combinations in the script and 3D model. The component does not yet have the functionality to enable the user to reinstate or save all of the solutions for further use and once this is closed they are no longer accessible. This is addressed by Rutten in blog posts as an area for the components development. Evidently, this is a drawback to producing a series of solutions using the script as they cannot be accessed again.

The solutions are organised by their percentage of accuracy, this being the percentage value they have to meeting the exact requirements input by the architect. For the purpose of this thesis the script was set to run for 200 generations, taking approximately 9 minutes for the solver to complete. *Figures 24* and *26* show the top 10% of layout combinations.

(GIF's of all results can be found on an external file accompanying this thesis)



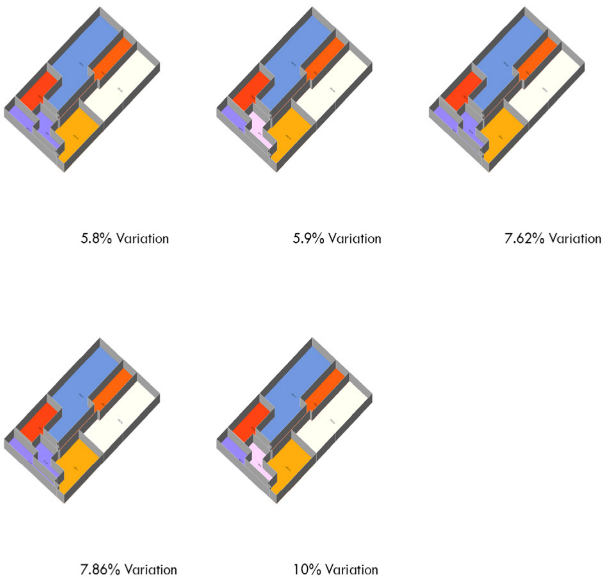


Figure 24. Plan view of the top 10% of layouts

Figure 26. Orthogonal view of the top 10% oflayouts

75% ACCURATE LAYOUTS

These are the layouts produced by Galapagos that are the top 25% in relation to the variation between the designers area inputs and the scripts output.

Looking at these combinations the fitness values are over 90% accurate, however the main critique of using an evolutionary solver within the script becomes evident. Once the solver selects a layout with a low percentage of variation it only selects variations in close proximity to itself to develop. This leads to the results being highly similar in design as their evolutions are internal layouts with little variation.

Available to view in the Rhino model space are the top 25% of genomes, seen here in *figures 28* and *30*.

The workflow output from grasshopper script to visual result in Rhino model space is one of the benefits of using a visual scripting programme. Whilst the variables and geometry exist in the Grasshopper interface the visual output can be controlled by the architect and viewed in the Rhino viewport to enable a seamless workflow from script to design. The colours and area notations have been controlled through the script and enable for a clear reading of the output.

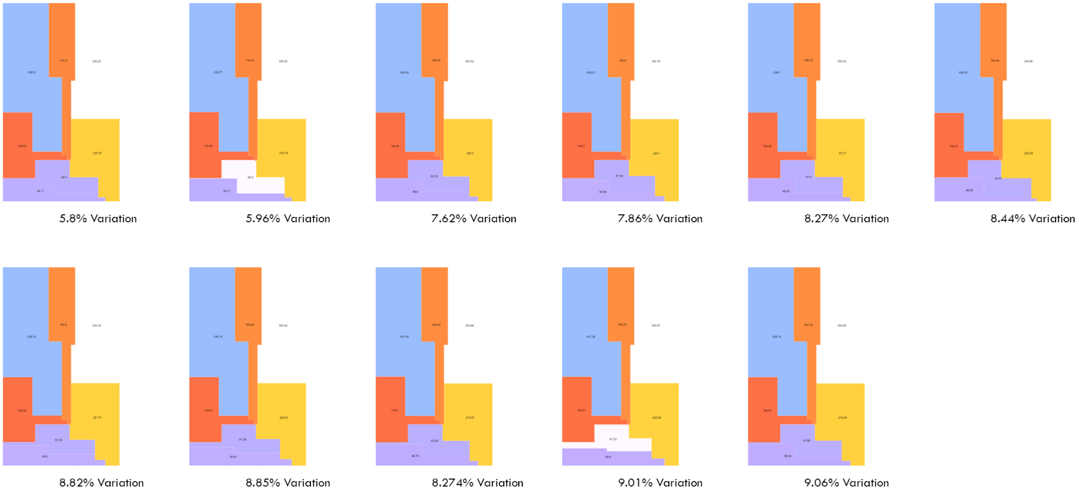


Figure 28. Plan view of the top 25% of layouts

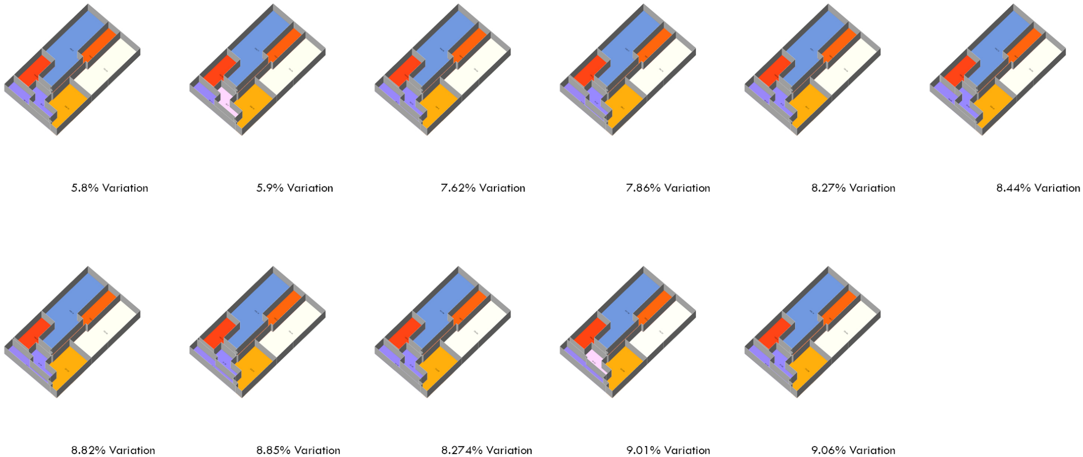


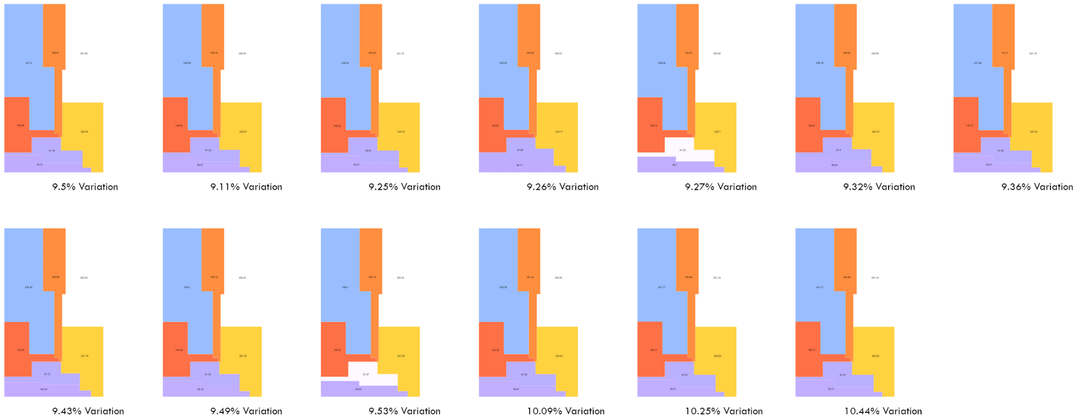
Figure 30. Orthogonal view of the top 25% of layouts

50% ACCURATE LAYOUTS

These are the layouts produced by Galapagos that are the top 50% in relation to the variation between the designers area inputs and the scripts output.

The third set of classifications the solver provides for the user is the top 50% of layout solutions. These layouts have a higher level of variation, yet again, they have been generated with the dominant solution. Since all of the evloutions are designed to improve the quality of a solution using a generation to generation type basis they have a tendency to reduce the 'bio-diversity' in a population[64]. This leads to a reduced level of diversity in a series of internal layouts and the building design is limited in differences.

[64] The limited nature of Galapagos to produce varied bio-diversity in its results at grasshopper level is recognised by tis developer in his blog post following the AA lecture Computing Architectural Concepts. The post deals with evolutionary solvers in general but uses Rhino, Grasshopper and Galapagos to demonstrate the topics. Rutten, D. 2010. **Evolutionary Principles applied to Problem Solving.** Available online at: [http://www.grasshopper3d.com/profiles/blogs/evolutionary-principles] Accessed 25/03/2018



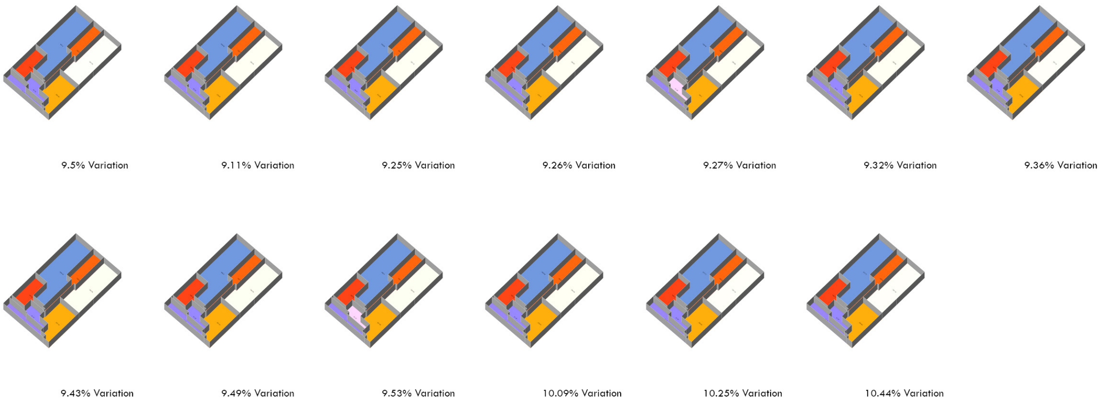


Figure 32. Plan view of the top 50% of layouts

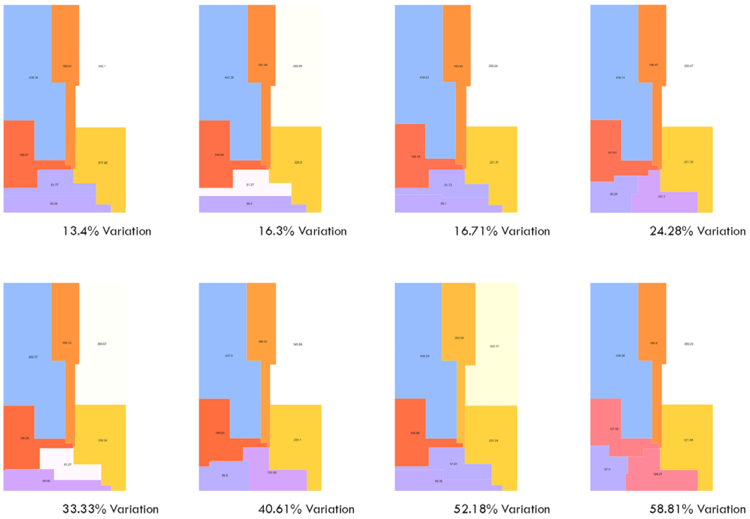
Figure 34. Orthogonal view of the top 50% of layouts

REMAINING LAYOUTS

These are the remaining layouts produced by Galapagos that have been determined as having the highest variation between the designers area inputs and the scripts output.

Amongst the top layouts the solver also provides the architect with a selection of designs that don't fit the specific area requirements but do allocate the number of rooms selected in the outlined space. Below, in *figures 36* and *38* are the remaining layouts produced by Galapagos.

It is evident in these solutions that there is a little more variation as the solutions are further away from the goal. Most evident in the solution with 58.81 variation can the allocation of different spatial arrangement be seen, yet the solutions shown are still a variant of the dominant layout. Although the solver was allowed to run for 200 evolutions, it does not store all possible solutions meaning the user cannot view different spatial allocations to these even if it was desired.



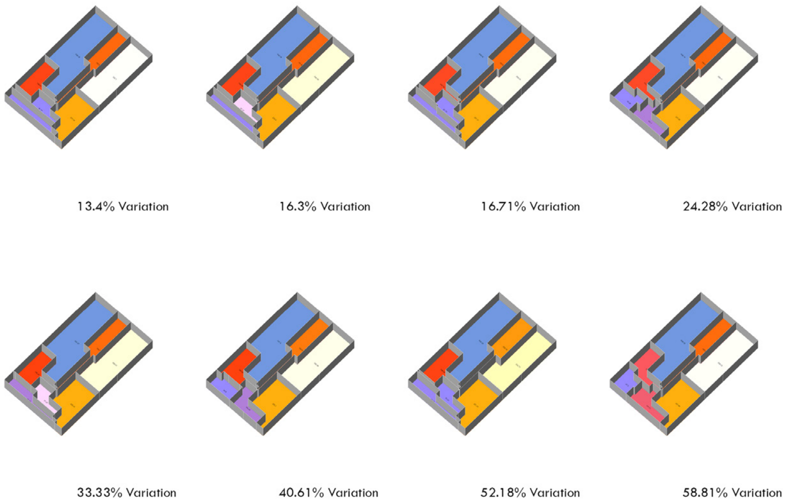


Figure 36. Plan view of all remaining layouts

Figure 38. Orthogonal view of all remaining layouts

The tests in part 2 demonstrate the ability a computer has to carry out an architectural design task. They recognise the increasing use of visual scripting tools in architecture. These tools are continuously updated and developed to become more sophisticated aids of modelling. This thesis recognises that scripting design is a task undertaken by other architects and designers as technology changes the way we work. However, before the physical testing and definition creation it was unknown to the author as to if was possible without significant software knowledge.

It was predicted on the timeline rating the automatability of RIBA Stage 2 *(figure 8)* that scheme layouts had an ARL of 3. In addition to this, Lauren Poon suggested the next step for automated design is to set up a computational solver. The scripting task in part 2 showed success in developing an arrangement of spaces for an internal building layout. However, the limitations of software are apparent in the results. The most inherent drawback of this script is the minimal variables it allowed the architect to input. It is easy when drawing a sketch scheme to consider light, wall arrangement, and corridor width or window placement. The current capabilities of Galapagos allow for compound testing with several variables, known as a compound fitness function. However, the drawback of this is it requires a significant amount of developement time and coding knowledge that many architects do not have.

These limitations are also evident the layout results in *figures 24-39,* where the central orange room has an area of 179.01m^2. The initial parameters set in the data input and brief specified this room as the bathroom and it had a desired area of 177.63m^2. The tests demonstrate the ability of the script to produce a room size close to the desired size, but the visual result shows the space as a long and narrow room. As an architectural space, this is undesirable and would not be a successful layout design. The script requires more variables to input a series of size constraints for the internal rooms.

The second evident limitation is the nature of the evolutionary solver to produce an optimised solution for only one internal layout. Recognised as a drawback to the script in the previous chapters a further test was carried out to search for a resolution. This test aimed to find out whether the beginning value of the points in the gene sliders that represented each room affected the final layout. To do this, the points were moved using the sliders before the Galapagos solver started. The results of this test supported it to be true and the internal layouts produced are displayed in Appendix 1. By finding this hypothesis to be true, the research has a broader possible application as it can provide the architect with more than one layout design.

PART 3 - CONCLUSION

WHAT DOES THIS MEAN FOR THE ARCHITECT?

3.1

UPDATING THE STAGES OF WORK

Section 3.1 looks at how this research would affect the current RIBA Stages of Work. It analyses the RIBA and BIM stages of work and proposes a series of updated work stages with how automation and technology could affect each stage.

'We're seeing a whole breakdown of the RIBA stages because you are making stage 4 decisions at stage 0. What used to be a decision that got made a year into the process, we are making at feasibility stage, so it kind of flips the whole thing on its head'[65]

Established in 1963, the current RIBA work stages[66] were revised in 2013 in an attempt to account for the way the workflow of an architect has changed. Recognising that the way architects work through a project has become increasingly less structured toward a straight set of 8 stages the new online tool allows for practices to customise their own plan.

As of 2011, all public centrally-procured government projects[67] are required to be collaborative with building information modelling (BIM). In 2014 the British Standards Institution (BSI) and the National Building Specification (NBS) published the BIM stages of work. Similar to the RIBA stages of work it details the step-by-step process of a construction project through BIM. Yet there is still a criticism of the RIBA stages, that being that they do not fully incorporate the changes BIM introduced to the building process. In his BIMPlus article Steven Hunt asserts that there is a 'disconnect between the client's expectations of RIBA stages and BIM design methodology'[68].

With this misalignment between the RIBA and BIM stages of work, the main grey area consists of tasks such as data-focused delivery or detailed technical specifications made possible through the addition of data. The issue here, being that many of these tasks do not fall under any of the typical stages of work, leaving practices at a difficult point in how to accurately charge fees for them. Without accurately described

[65] Quote refers to an interview with **Lauren Poon** on how data changes the design process, transcript found in Appendix 3.0.

[66] First developed in 1963, the **RIBA Plan of Work** is the definitive UK model for the building design and construction process. The Plan of Work now includes this online resource enabling professionals to browse, customise and download a plan of work. It is intuitive to use with on-screen help at each stage. Available online at: [https://www.ribaplanofwork.com/] Accessed 27.03.18

tasks in the documentation that clients use to understand design services offered by architects, there becomes a question as to why the costs for products change.

'Measuring data points all the way through requires a complete restructuring of what our services are as an architect.'[69]

If there is a growing issue surrounding the current work stages and the products or services architects offer due to the introduction of BIM, it is inevitable that with the rise of technology changing the role even further there will need to be a re-evaluation of the design stages.

'If you look back at the original charter of the RIBA its really radical. It says that the art and science of building is not just a private good, but a public good by definition.[70]

This part of the thesis looks at the current RIBA stages and taking into account the research conducted and the effects of technology on the profession. Timeline 4 *(Figure 40)* proposes a timeline for the updated stages of work and looks at how each will change.

[67] In this briefing sheet, author Barry Tuckwood, on behalf of the BIM Action Group, provides an explanation of the UK Government's BIM Mandate. This includes an in-depth analysis of each step of the mandate. Tuckwood, B. 2016. **BIM Mandate and BIM in legislation: There is a BIM Mandate, how does it work?** Available online at: https://www.ice.org.uk/knowledge-and-resources/briefing-sheet/bim-mandate-and-bim-in-legislation-there-is-a-bim

[68] Hunt, S. 2016. **RIBA stages and BIM: You can't play a new game with old rules.** Accessed online at: http://www.bimplus.co.uk/people/riba-stages-2and-bim6-you-cant-pl6ay-new-game-old/

[69] Poon, L. Appendix 3.0

[70] Quote refers to an interveiw with Alastair Parvin found in Appendix 1.

TIMELINE
4

UPDATING THE STAGES OF WORK

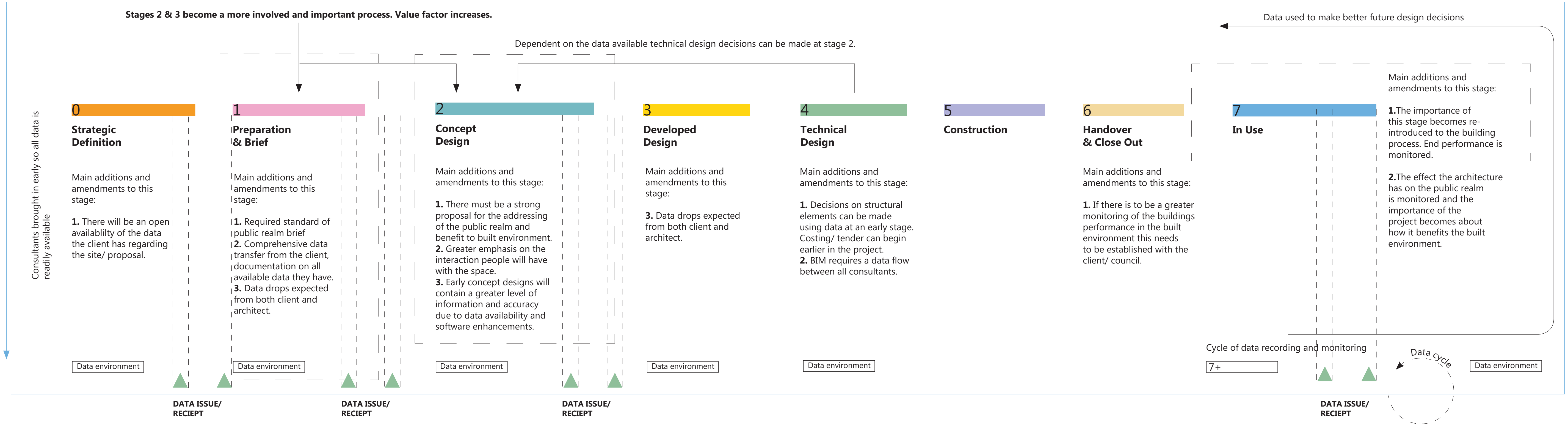
This proposal is a timeline for the updated stages of work and looks at how each will change.

(figure 40)

UPDATING THE WORK STAGES

This timeline looks at the current RIBA stages and taking into account the research conducted and the effects of technology on the profession.

Figure 40



THE ARCHITECT

The conclusion in the next chapter looks at how the tests in this this thesis can be applied to a greater scope within architectural design. They focus primarily on the effects automation will have on the architecture profession. Followed by a personal reflection from the author.

3.2

EFFECTS ON THE PROFESSION

Section 3.2 concludes with the effects this research could have on the architectural profession and how the role of the architect could change in the future.

This thesis predicted that the addition of automated machines into the workflow of an architect would have broad implications for the role. The introduction of software tools that can employ a level of creative thinking means that the tasks once constrained to the role of the architect will change. Technology will alter the fundamental elements of a design process and it will be the decision for the architects of the future as to how they will shape their role.

The current working process of an architect was established in the interviews to find areas in which automation could infiltrate. While one architect could not imagine where automation could work with the profession the other three had opinions on how architects can use data and computational design. These opinions varied from automated systems that meant entire projects could be completed in-house, to data-driven decisions that could produce results with the highest amount of value.

To find the areas of a design process that could be automated, the thesis established the automation readiness levels (ARL's). In doing so, this thesis provided a framework for architectural design tasks to be evaluated by how automatable they are. By evaluating each of the RIBA work stages using these, it is evident that almost every stage had tasks that were both susceptible to automation and those that had a higher resistance. Taking this into account, a combined design process using automation and architects could affect every stage of a construction process.

The thesis rated RIBA Stage 2 at an overall ARL of 4 and 7 and the scripting tests in part 2 supported this rating by demonstrating the capability and limitations of the current software. In the detailed timeline for RIBA Stage 2 internal layout tasks were rated at 3 and 7. The tests in part 2 chose this task to automate by breaking it down into a series of behaviour patterns and numerical inputs.

While it was successful in producing internal layouts, the main limitation was that it could not easily measure combined variable such as rooms with specified connections. In being unable to do this, the test supports the levels assigned, as while the task can be broken into numerical data it lacked the manual dexterity and creative intelligence of the architect. However, this thesis produced one layout in a relatively short amount of time, therefore, demonstrating the ability architects have to automate some work processes.

Considering the broader application of the tests in this thesis, the introduction of an automated design tool that can understand data and produce an outcome would be a powerful addition to the architect's toolkit. With computer systems such as Space Syntax becoming increasingly popular, the science behind how people interact with spaces and the built environment is changing how we design our cities. Not only do these technologies offer designers the opportunity to evaluate their work it allows them to simulate their proposals using real-time data flows. The reality of the new technologies does not pose an unemployment crisis, but it requires architects to apply a certain amount of flexibility to their job title.

In concluding by proposing how technology could change the RIBA Stages of Work the thesis aims to offer knowledge on how architects can incorporate this flexibility. The thesis proposes an updated set of work stages with both tasks from the digital plan of work and the RIBA plan of work. Influenced by the knowledge in the previous chapters, this update uses variables indicating occupations that were non-susceptible to automation. It also incorporated knowledge gained through the scripting tests of the automatability of architectural tasks.

By allowing the repetitive tasks of an architect to be automated those that require all the skills to resist automation become more prominent as a result. If the optimisation of design, schedules, layouts and massing could be automated then knowledge retaining to social perception, creative skill, fine art and originality can be brought forth as more pertinent in the design process. Should architects recognise this and work with automation, then the reality of automating these design processes inevitably means better designing of the built environment and better, more socially intelligent cities.

3.3 -

PERSONAL REFLECTION

As an architecture student, in my final years of study before going on to gaining professional accreditation as an architect, the topic of how the role will change in the future is one I find incredibly important. It is no secret that automation and technology can affect millions of jobs worldwide, this thesis was just the start of the conversation that is 'what will the architect of the future be like'. It is near impossible to imagine the future - just as 10 years ago most of the technology we have now couldn't have been predicted, the technology in the next 10 years will most likely be different to anything speculated upon now.

Upon writing this thesis, my position in the subject is that in order to remain current in a world defined by technology, architects should embrace new advancements and work in tandem with the plethora of intelligent systems available. As architects we have an incredible training process, one in which we learn to develop skills not only in design but how to understand the social, spatial and emotive properties of the built environment. Could the next generation of the architect be one that sees these skills utilized to the fullest, and in turn relinquish some tasks of the role to creative machines of the future.

APPENDIX

1. **Layout results with randomized point variables**
2. Interview with Alastair Parvin
3. **Interview with Lauren Poon**
4. Interview with Jeff Kahane
5. **Interview with William Beeston**
6. Interview Questions

APPENDIX 1

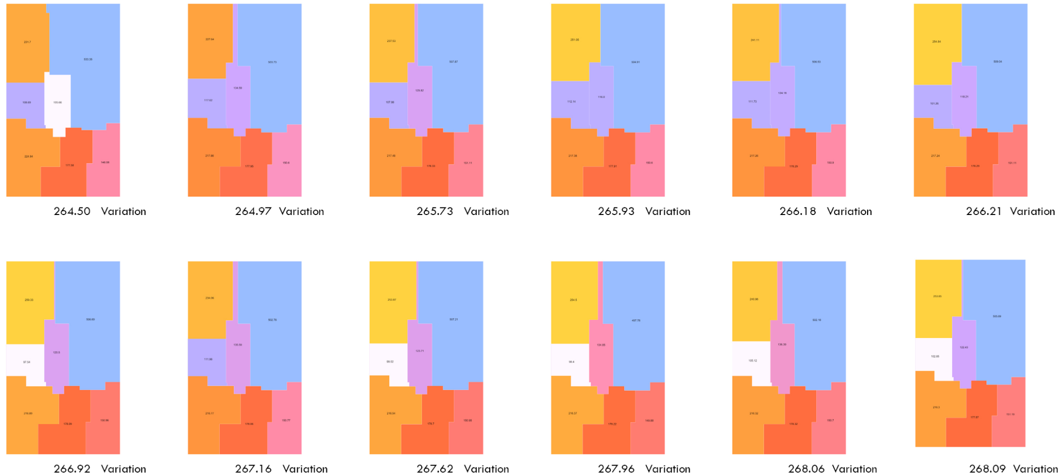
LAYOUTS PRODUCED WITH VARIED POINT DISTRIBUTION

1 – TESTING VARIABLE RANDOMISATION.

This series of layout solutions were produced to test the hypothesis that if the points were randomized prior to the solver starting it would produce a different layout solution each time.

In the first randomisation the solver was let to run for 200 layouts, identical to the set contained in the first results. Whilst this series supports the hypothesis that the Galapagos component can produce different layouts dependent on its starting condition it finished with a minimum area deviation of 254.12.

By supporting the hypothesis that the definition can produce varied layouts each time, if the points are re-distributed differently to the prior solution, results in a wider application of this research.



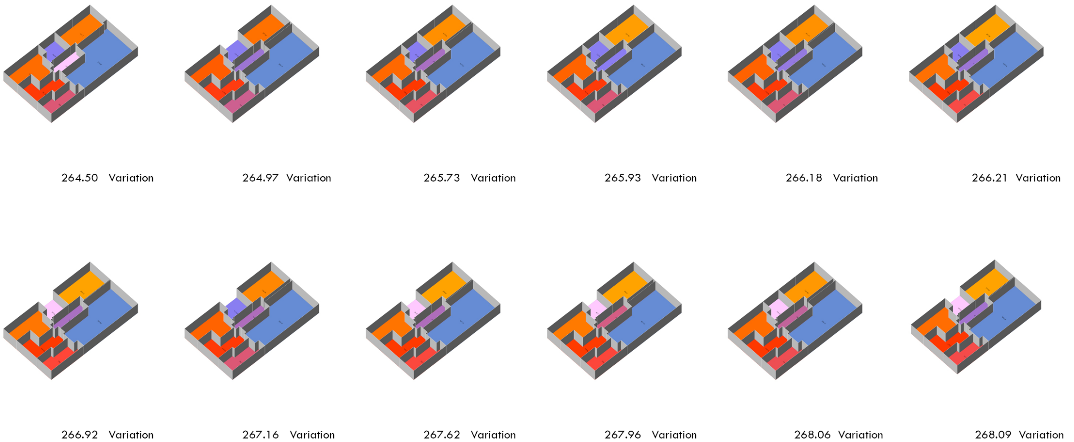


Figure 41. Randomisation of initial point variable test 1

Figure 42. Randomisation of initial point variables test 1 orthogonal view

This test was then run a second time, again the initial point variables were changed prior to the solver running. These figures are a recording of the top 25% of layouts. The minimum area deviation in this set of solutions was 42.57.

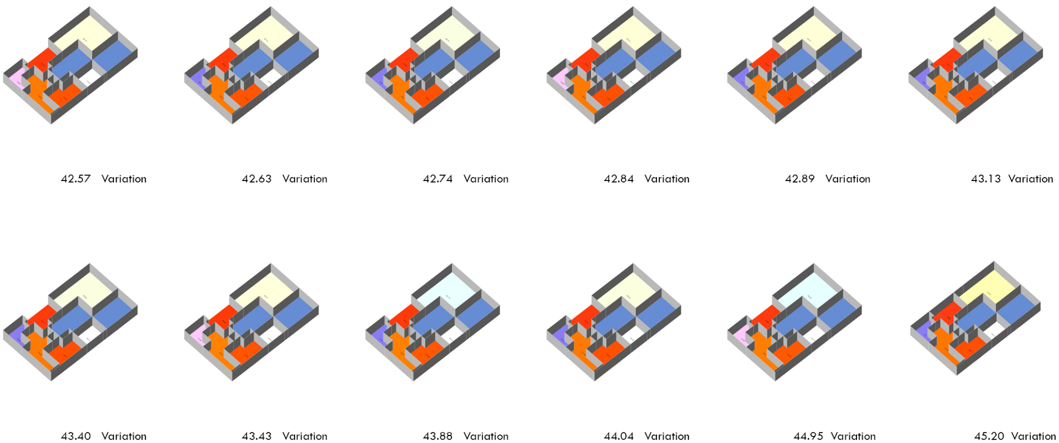


Figure 43. Randomisation of initial point variable test 2

Figure 44. Randomisation of initial point variables test 2 orthogonal view

To further support the hypothesis this test was run a third time and the top 25% of layouts recorded in the figures below. From these tests the solver was left to run for the same number of results as the initial tests, which is 200. The minimum area deviation in this set of solutions was 22.66.

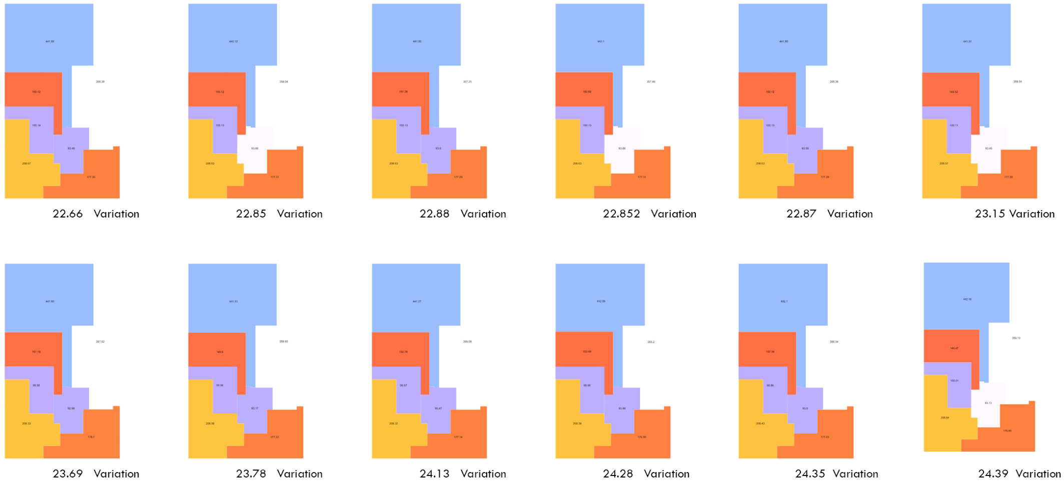


Figure 45. Randomisation of initial point variable test 3

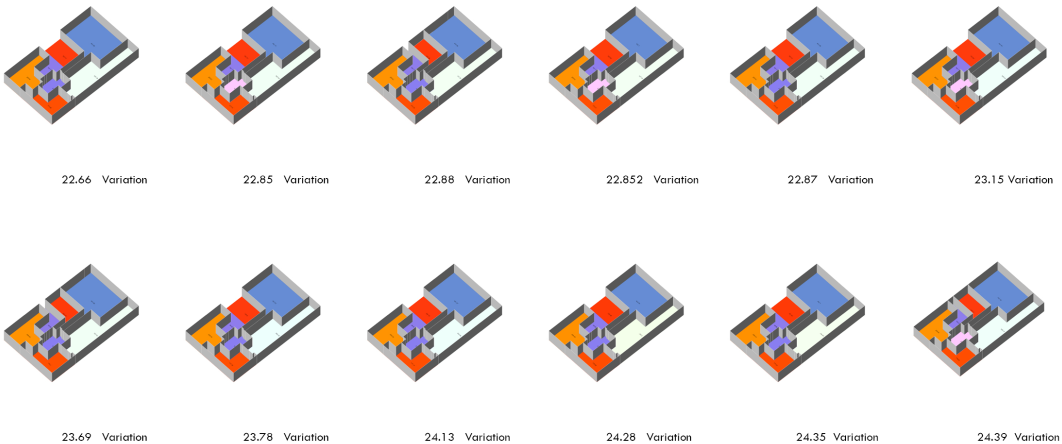


Figure 46. Randomisation of initial point variables test 3 orthogonal view

GAINING ACCURACY WITHIN THE RESULTS

TEST RUN 12

This process was then completed for 10 possible layout solutions, the same number of results were produced (200) for the same 7 room areas. Considering this capability, the research can have a much broader application to the knowledge of architectural design. Although the script is still in its most simple stages and only tests one variable, its ability to produce a varied level of optimised layout solutions means it behaves in a way similar to an architect looking for the best design solution.

During test run 12 the solver produced a genome that only had 0.4 in area deviation. This was the closest solution recorded during the testing process and can be seen in f*igure 48*.

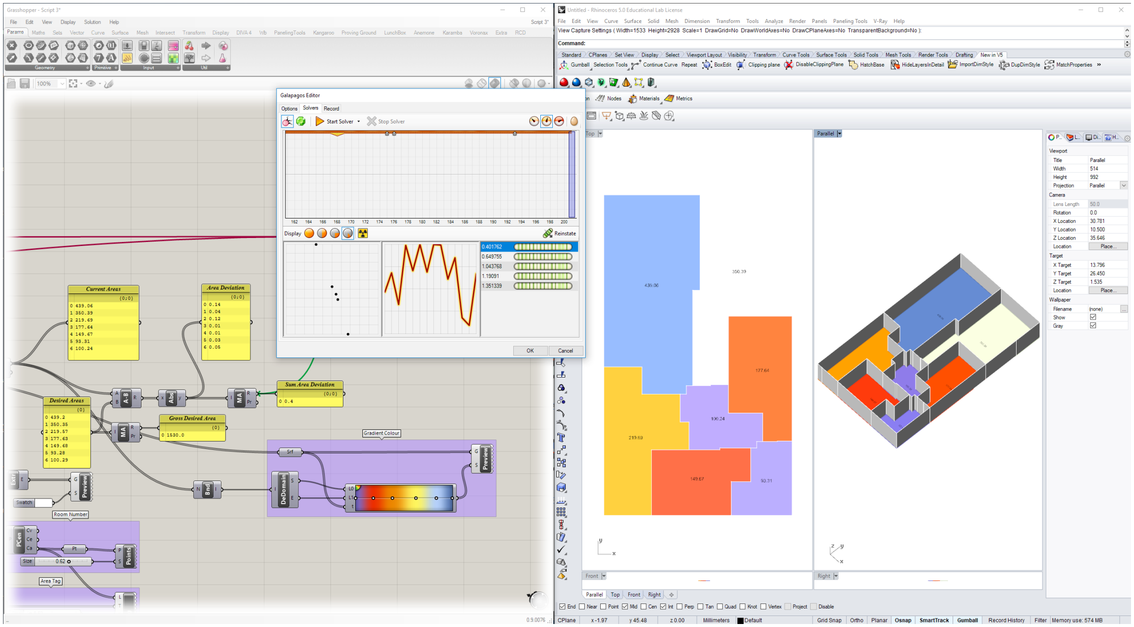


Figure 48. Total variation measured at 0.4

APPENDIX 2

A conversation on automation with Alastair Parvin, Wiki House Foundation

12th February, 2018

CC: It will be best to start of this conversation by showing you my current abstract so you can get an understanding of the topic I have decided to tackle for my thesis. [presenting thesis abstract and structure notes]

AP: What's kind of interesting to bear in the back of your mind is that your also kind of doing this stage of framing and aggregating things is one, what tasks are automated and what tasks are no longer needed, the other one is there is a lot of lazy thinking or bad practice which is bundling Ai – most Ai is not Ai.

Understanding the difference between data at the bottom, the data is just stuff, information which is structured data, so it is data that has been given some ordering structure that can therefore be useful, then you have a whole zone which can be called automation. I have heard this described as the little brother of Ai, but automation is very much your 'if x then y' repetitive task automation and they can be more and more complex based on conditional algorithms. Then you have machine learning and you have AI that blurs into the theory of and actual Ai.

On top of the data you have pattern and knowledge and maybe even beyond knowledge you could have philosophy, which is an interesting question of why you're doing something. Then the interesting thing is that automation deals with the realms of taking information and giving it patterns, machine learning is basically data correlation mapping but that in itself is not AI. AI is the ability to do reasoning and responding so even when we can crunch huge amounts of data, for example the machine playing chess, clearly that is beginning to bridge the gap between machine learning and Ai but it is still not asking the question of why am I playing this game.

CC: Whenever I touch that then you ask the question again of why, why would you want that and why would you want the machine to be able to ask the question?

AP: This always comes back to Cedric Price and the question of 'technology is the answer but what was the question but that is an interesting thing that you have delicately avoided in your abstract which is good.

CC: So, the questions I have at the moment are discussing the RIBA stages of work, I know you're doing Wiki House and open source architecture but what would you actually describe your job role as at the moment.

AP: There's a nice Linus Torvalds thing about the job of every open source founder is to make yourself unemployed and I think that is true of anyone in technology. In theory we became entrepreneurs, I quite like the idea if there's such a thing as a civic entrepreneur but it is not a thing you can be which is basically someone who is trying to be entrepreneurial about the systems that we use. A kind of middle operating ground, I personally feel like a strategic designer, when I get out of bed in the morning that's what I think I am. So, I am a designer but again to quote Cedric Price I am not interested in bridges but I am interested in how to get the other side. I'm not interested in hospitals but I'm interested in healthcare - that's what I feel like.

CC: One of the things when you talked at the RA that was interesting [refers to previous talk], was that you talked about how automation and automating the architect's role and the bits that we don't need to do would mean that we could spend more time essentially doing what we always thought we would do as architects – making people's lives better.

AP: One of the things is what's left to own in the future and what is left to do and the good news is there is loads left to do. So, you can almost take that conversation off from square one and there's two ways I always answer that question and I'm sure it came up at the RA is 'it's going to make us unemployed' but no. Architecture is responsible for, its estimated around 2% of the built environment, meanwhile by 2050 we have to support a global population of around 9.5 billion on planet Earth without fossil fuels, the idea that we are going to run out of design problems any time soon is absurd. What isn't justifiable is that anyone will be earning a wage producing the same solution over and over again which is what our economy currently does. There will always be a layer which is seeing whatever tools and technology we have and asking questions of those tools and applying them. No matter how good Ai gets, and by the way it could get really good, architects always say 'well robots won't be able to make aesthetic judgements' but what is do you think the golden mean is?

CC: Did you read the part I wrote about that, that we like to see creation and creativity as an exclusively human trait and its becoming more and more not. I see my thesis as pertinent to architectural knowledge because people avoid it, everybody skips around the topic and if you look up architecture and automation you find people talking about a small part of it but most people will say 'don't worry you are still going to have a job'.

AP: It is just going to be a different job, so this also goes back to the things were working with on automation now about how we try and structure it because if we think of a box as being like animals in a zoo and they must have keepers. In some cases, the keepers of the box must be everybody and it must be open and transparent because it's going to have such huge ethical implications to an algorithm. If you make shoes you can sit there and make shoes or you can make a machine and you can sit and check that the machine is doing the right job, if the machine then gets a function that can then understand when it gets a problem and can fix itself then your job now is to think 'well why do we need shoes' or what could we do better. If were smart and we make the right economic and democratic discourse environment around technology, then it can only ever be a good thing – that sounds ridiculously naïve because it clearly isn't but it could be. If we got that right then there's no reason why it wouldn't be the case because it just means you're moving humans to this greater and greater abundance, and were saying the only destination of that is where we have fantastic abundance and we have clean energy. – and we would work.

CC: What do you think we would do, out of interest?

AP: It would be human work, there was always looking after people, educating people, even when robots are really good at that humans will still have something quite good about them. Also being a citizen, is a form of work – when I go and start a riot to say, bring down my government, that is a way of working for the betterment of my society - even if I'm wrong. So, being a citizen is a big thing that's being overlooking in the basic universal income, were seeing basic universal income as a kind of methadone which is going to pay you to go and sit on the beach but that's not what humans do. If you look at, I don't know how old your parents are but mine are at the point where they have retired now, and the whole country is being run by them [not my parents but the older generation] - they are volunteering on the canal networks etc, there is always more work to be done. It might be starting a campaign group against an algorithm that's killing people, but the key thing is to put in place the political structures and technical structures to build into that kind of future and opposed to the highly centralized capitalised one.

CC: If I give you a little bit of a back story, maybe to my interest and why I am writing the thesis in general is that last year, [I know you talked about it at the RA] I was introduced to the concept of the fully automated luxury communists. I met Jon Goodbun, who was my history and theory tutor and we ended up on that topic of universal basic income and post work. That then brought me on to luxury for everybody and what is that, which for me was education, healthcare, sanitation and water and that was the luxury rather than the connotation of luxury we have at the moment.

AP: It's the same as all communism, it is an ideal based on an impossible power position and the problem is to bring about that level of power control requires centralisation which would corrupt people. That was the problem, you ended up with people who could only bring about revolution, revolution involved guns and then you have a committee of people who control the guns. It almost always ends badly, whereas the promising version of the future is not universal basic communism but universal basic democracy. Democracy is competitive and things do go wrong but there are actually decent institutions around that to allow that continuous process of working out what is right and for people to have rights that are defended.

CC: I think they have re-coined it now to Fully Automated Luxury Equality

AP: Again, I don't even think equality is what you want, less inequality is good but not absolute equality.

CC: There is definitely an interesting debate to be had there with what they want and what works in society.

AP: The good news is you don't need to achieve that, you just need to achieve democracy or even half close to democracy and you're on the right track.

CC: Alongside thesis we have to produce a design project, my current design project is focusing on this world however it might be, I think I am focusing on 50 years in the future and what I've proposed is that if we don't have the same capitalized labour that we do now and things are automated that we become more artisanal.

AP: In theory yes, you could, this is whole philosophical question that hopefully you could have a more enlightened society but some people will do it and it will look like craft, some people will do it and it will look like philosophy and for some it will look like decadence, for some people it will look like forming an underground movement – it doesn't really matter the whole point is that you have the capacity to choose.

AP: So the interesting thing about this, and I think it's clever of your thesis to start with the architect, but to remember that the architect isn't the start. The architects and the stages of work were historically a pretty recent invention so the question we have used to find our way into this, is to think about the questions of knowledge. If you take it as a given, lets fix on something that is a production of our built environment it requires knowledge. If you take any building the whole thing about it is that mechanically it isn't that complicated, to say a plane or a missile, but none the less it is socio and politically complicated because there are so many things. There's making sure it doesn't fall down, there's who's liable if it does, there's the acoustic performance of it, the environmental performance of it, there's control, security, access – so many different complex layers required.

So the question is, where does that knowledge come from? The thing that is important to remember is that throughout history there is no such thing as the architect, you essentially had an open source pool of knowledge which was vernacular design. In fact, one of the ones we encountered for the Wiki house project is the scarf joint which is really interesting and there are evolved versions of this joint. So there are evolved versions of this joint which was probably documented in pattern books but predominantly it is handed down from craft person to apprentice and so on. Understanding the history of patterns is important, which again is why we are interested in Christopher Alexander, then you have the evolution of patterns, the thing that then happens is at a certain point got more complicated. Societies and buildings became more complex and needed to do more stuff at scale and so what happened, is that where previously in this role where you had a bunch of design patterns which were handed down, you needed more and so started making pattern books. There became some kind of educatory process where you could capture knowledge indirectly as well as directly, but then none the less all of this could be held in the head of, or at least the responsibility of, one person which is the master builder. As too much burden fell on this role at this point the architect begins to emerge in history, almost at the moment architects begin to emerge they start to distance themselves from the responsibility of this role and they started to see themselves as artists. What you begin to get for the first time in history is a division of the specialisms into the architect, the engineer etc all being part of royal charters and societies.

The Royal charters being such important things, most of them have been eroded over time as if course most people adjust their policies over time for their pay check. If you look back at the original charter of the RIBA its really radical, it basically says that the art and science of building is not just a private good but a public good by definition [not in these words but as good as any other] and the charter of the profession is that we had a responsibility to serve the public good in the built environment. Of course over time it became an industry lobbying exercise and became more and more marginalised from most people's experience in the built environment.

So the process of making a building became a process of getting the knowledge out of their heads, which became an increasing problem as they all have competing industries and conflicting interest, so it means drawing and checking. If you actually follow an architect round, particularly a senior architect, very little of their day is spent designing. Most of it is taken up by emails and phone calls, you have this incredibly labour intensive process of checking and rechecking and drawing and redrawing meaning every building is designed from scratch several times over. The issue with this of course means that you begin to have complete uncertainty and no one knows what it's going to cost until it's been built, creating huge amounts of risk – risk freezes out small players, ordinary players which means only rich players can afford to do it. Structurally it's the more speculative capital firms.

CC: I actually worked for a large firm during my part 1 which was interesting and you get to see it first-hand.

AP: Its actually fascinating, so we have structures like D&B contracting etc who do essentially no building at all themselves they are just risk financialisation vehicles and beyond that we have speculative developers. So we have this huge problem and it escalates, once everyone is in this risk averse culture A you can innovate but B the moment anything starts going over budget everyone keeps doing more work and trying to push risk and blame on others. Which in turn means costs escalate and people work even harder to avoid risk leading to functions of bad procurement.

What's really important to underrated is only at the centre of this circle are the problem of actually doing the drawings, most of the work going on in this spiral is to do with trust and the human to human interaction, were still trying to get our heads around that but it's a really interesting element to this conversation. Obviously everyone's looking at digital to do this, the reason we don't think BIM does it on its own is that our current view of BIM and all of these programs is that all they've really done is take a paper drawing board and digitalize it.

CC: It's interesting to talk to someone who has a really in depth opinion on automation in design because most people tend to avoid the conversation and architects often try not to talk about it or think about it.

AP: Right - this is problem, especially in architecture right now, the truth is people are thinking about it just not in architecture. This is a really interesting point, we are not the first people, not surprisingly, to encounter this – in the 1980's a practice emerged called 'knowledge based engineering' and I encourage you to google this. It is actually insanely important, when you read the thing about knowledge based engineering the language they used is partly techy, it used terms such as heuristics. So heuristics being a rule of thumb, for example in this process when an architect is speaking to a QS and saying 'I want to paint it red' and the qs is saying 'oh it's going to cost you', it's this opacity to get a rule of thumb.

When we were just starting out with Wiki house, Johnny was playing with some desks and we suddenly realised that because we could see the manufacturing files we could see the changing of an angle of one leg by 5 degrees meant we could fit them all on one sheet and reduce the price - so suddenly by having this rule of thumb we could be creative in the economic sense.

The reason why this was adopted by companies such as Boeing and aerospace was because they realised that the design of an aeroplane is a complex business which means you have about 50 different engineers around a table arguing with each other. It raises the question as to why hasn't this been adopted by the built environment? And this is really crucial, which is that buildings are not technically complicated but they are politically incredibly complicated but it's about the fact that they all happen in house. You can make a knowledge based engineering piece of software by taking knowledge and turning it into an if this then than grasshopper or adaptive script. So you can code it in a machine readable format, you can tie that to a spreadsheet and you start to have all the rule based data and suddenly you have a series of bots maintained by a person. What this is then giving out is a series of heuristic rules with real time implications, but of course they could do that because it's in house. So the first stage of our industrial revolutions is that we have computers and digitalisations but not the web its always happening in house - not just technically but legally so you can absorb all that trust. In the built environment we have a much bigger problem because not only do we have all these specialists but they are not all in house and therefore they are against each other.

CC: I think this is something I've touched on in other essays, the fact that the first people in the chain to go will be the consultants before the architects.

AP: I think architects will be almost the last to go, definitely before health experts and anthologists but that's because architects have been really bad at doing their job. If architects got really, and I think they will have to, got really serious about user experience in the built environment we would survive a lot longer.
The key mechanism that we are perusing is that we have this knowledge problem, we have the ability to deal with the knowledge problem by using automation by taking a bunch of these little rule based scripts and letting them talk to each other. We now have two possible ways we could apply this to the built environment, 1 we could go for the all in house model – most of the prefabrication companies are doing, this but of course they find it really difficult to scale. You could do a Henry Ford, you could do an Uber meets Henry Ford, where one company probably google backed will become so good that within the stack they can bring all that specialism in house and deal with diversity.

There's two possible futures, we either sit and we wait for a massive Silicon Valley company to bring black box automation and they will build not just automation but on top of that Ai's machine learning that can process all kinds of cool stuff but we won't have an idea what is going on in the box. Without going too far down into that conversation we can begin to imagine some of the implications of that but it will no doubt have a bias dependent on who the main funders were.

The moment you can measure the research between scientific data, mapped to a design program, mapped to a design and back to a design outcome, hook that on to a smart contract and you can do something incredible. You can eliminate the risk, pay for a loan to carry out the construction at a better quality knowing that it's going to pay off because for the first time you can actually see the implications of a design pattern rather than it just being in a designer's head.

The other option, which is no doubt the one we're perusing is to say well what if we take the same approach to this but not the Silicon Valley approach but the Tim Berners Lee model of the world wide web which is 'what if we do this distributed open automation' which is what we're working on. We are working on really simple mechanisms like a decision tree format or like a grasshopper format which is similar and it doesn't plug to offline desktop software but in the language of JavaScript etc. Effectively then each pattern has an API can then speak to others, this is the concept that we call the pattern web which is a concept that may be ambitious of open distributed automation as opposed to centralised digital automation. So in this model we would be inviting different institutions and organisations to create their own pattern and really own it, and be legally liable which is another issue were trying to work through.

CC: Well of course, if a machine tells you to do it who is legally liable?

AP: In theory you've got a certification stacked so you can track back, at the moment professionals take out professional indemnity insurance against the drawings that they issue and the risk is limited by the size of the project. But if I make a bot that can suddenly become popular overnight and can produce a million buildings then by definition you must be liable at that code at some level but how do you control and insure for that liability?

It's one of the questions that is lurking in the back of our heads at the moment that is this huge legal paradigm change coming up with automation, which is if you're the keeper of a bot, when you send out drawing you can get pii on those drawings but if you send out a bot you have to get pii on the bot which will be really interesting. What's cool about this is you can now have multiple different perspectives, and also that its modular so you can add things in. So say if BRE turn up with an energy calculator of someone else turns up with a calculator and they have loads of data on say supply chain ethics research, you can see if any of the projects your specifying has had bad labour supply in their history.

CC: So it's like plugging an Excel file into grasshopper, fill it with data and ask it to read it for you?

AP: Well this might be a hugely optimistic vision but it's what Tim Berners Lee calls the semantic web applied to the built environment. This idea of the pattern web is obviously insanely valuable because all of the things we used to spend hours on, as this is going back to the point at the beginning about thing you don't have to do anymore don't need to be done anymore. We think that's a more realistic view of automation where you can accept that each one of these has a different specialist of a set of specialists. There are two main questions that it raises at the end which are ownership and maintenance of these, which is what is our role in the future – it is the keeper of these bots and the question of transparency.

The question is just will architects be savvy enough, will they understand enough of how this stuff is actually working to participate in the conversation?

APPENDIX 3

A conversation on computational design and the future of data driven design with Lauren Poon, CallisonRTKL

19th February, 2018

CC: What I have done with my other interviews is to start with my abstract, so you can have an introduction into what it is I'm doing. I then have a few questions that go a bit off path, I have found it really helps get a bit of a back story. [Presenting thesis abstract]

So, I sent out a tweet looking for architects to interview and your friend Ashley got back to me, I'd just like to know a little bit of a back story and why he thought of you when it comes to architecture and technology.

LP: I am originally from Canada, I moved to London about two years ago and I have been working at CallisonRTKL for around 2 years and I have a major interest in tech also. I think particularly stemming from the fact I am a bit sceptical about technology but then oddly I have ended up in these roles where I have been using it primarily and responsible for advocating its use around the office. We have a delivery council which is a firm wide organisation with people from every office that looks at BIM practices and Revit. I did my first project in Revit about 10 years ago which was actually one of the first projects carried out by a firm in Canada and have been using it on and off ever since. I am interested in how architecture can use data and I'm currently doing a data course online at MIT.

Aside from that I've been partially responsible for pushing some automation practices here, so were using dynamo which is basically the equivalent of grasshopper in Revit and looking at how we can incorporate more computational design into our practices here. There are some practices using it but I think we can be better at measuring good design, there are some parts of design that are a dark art and there are other parts of it that we can and should be better at.

CC: What kind of areas do you think in particular when it comes to that?

LP: So, when it comes to things like maximising the number of rooms with a view to say a landmark, that's something that could be measured and being able to say this building form will give the most views to this church. I think that it something than we can and should be measuring with software, so looking at how we can integrate that more. I guess the other aspect of that is performance driven design which is partially our sustainability group here which again, firm wide, we call it performance based design which involves evidence based decision making and performance across people, planet, profit and that whole tri sector.

CC: I know you said you were quite sceptical and then have ended up pursuing that sort of path, it is almost what happened to me, I started it in fourth year and it has become a much bigger part of my design. In regards to your scepticism, how do you think automation will affect architecture and how do you think it is affecting architecture from a first-hand point of view?

LP: I think it's going to affect everything really, at the moment I couldn't tell you how it's affecting the whole thing. At the moment we are using it in chunks, we haven't been able to automate our entire workflow but I have done some diagramming for what our strategy might be going forward and I think that that would eventually be the case. I see that there is a fairly large disparity between the people or companies that are engaging with this conversation and ones that aren't and I think that it's probably going to end up with a big divide. My scepticism is more so that I think that we should always be looking at these things about 'what's the best outcome' and when I look around cities you say 'ok well, some of the best buildings aren't designed with Revit'.

LP: I think something that is a bit of a bug bearer for me is that everybody says it's going to be amazing and it's going to be so much better, but some of the best buildings actually don't use BIM and you can probably argue that the buildings that are using BIM are potentially worse than the ones that don't. I think that's because as a tool it hasn't been designed as much but I don't see technology as an answer to all of our questions.

CC: Do you think it will be a case of you either learn to adapt to technology or you simply don't exist in that future?

I think probably yeah, one of the better quotes I've heard about that is one by Walter Benjamin, he wrote about the changes when photography came into being, and people were saying photography was going to replace art or is it going to replace art. He said instead of asking whether one will replace the other we should be asking how one changes the nature of the other, and I think that's probably a better question when it comes to this to. With these things it doesn't mean that drawings are going to be obsolete but it changes the nature of architecture as the craft and how does architecture respond in an appropriate manner.

CC: I think that's quite the way I'm tying to go with the thesis at the moment, so to sit down and try to understand a little bit about how automation has changed jobs, obviously how it is changing it first-hand. But I've also sat down with somebody last week who uses absolutely nothing automated and it's about getting to understand the difference between the 'days in the life of''. The plan is then to pull out one of these integral parts and try and automate that to see what happens then to our role and what is that shift.

LP: I think what you're doing when you're working with automation and computational design is that you're designing a system and not an object and that will be the fundamental difference. So architects who are focused on designing a fixed thing like an object it's going to be more about crafting that thing and then at the other end of the scale with automation and systems design is that you're setting up a series of relationships. For us, or the way I see design going, is that computers are going to be able to do probably everything but they aren't going to be able to set objectives and they aren't going to be able to define the inputs and that will be where design will sit. So what do you feed it, what do you give a computational solver to solve and from there everything else feeds out of it.

I think where design sits in the process is going to fundamentally change and the role of design and the designer is going to spread probably from craft on one end and systems design at the other with a lot of stuff in the middle.

CC: For me, I feel like if architects pick this up then we can be more of the designer rather than working towards a way to lower costs and that's sort of the hypothesis I have set for my thesis, what do you think in that respect?

LP: The optimisation is one aspect for sure, you could definitely set an objective of 'what's the cheapest building', but the conversation we are having more with clients now is more about how do we get you the most value. The fundamental problem everybody has is that they have a fixed building in an environment that is constantly changing, so how do you maximize the value of that site. The conversations we try to have are not how can we make this the cheapest for you but how can we give you the most value on this property, and I think clients are starting to clue on to that too. The conversations we used to have were how we can get the most residential units and now we are hearing how many units does it make sense to build and that conversation is really encouraging.

There is a lot of clients that were having that discussion with and we've been actively seeking to work with people who have that mind-set too.

CC: I am going to try and put together a timeline, so can you think of a project that you have in Revit at the moment or one that you are using data. Can you give me a bit of an explanation as to the strategy you've taken to work with that and then I can take it apart and understand how that works?

LP: Since we are commercial architects the biggest piece of data we've always worked with is areas and every client wants to know what areas they are getting and all the cost and value flows out of that, so that is something we have been actively managing for clients since before Revit. I think that was one of the things that made Revit more appealing to us because some of those tasks of measuring became much easier and it became more about validating data than about generating it in the first place. It's definitely a shift of mind set and I think a lot of the industry is still coming round to the sense that you are modelling objects and not abstract lines and that's still something that we all collectively struggle with getting our heads around. You know, a wall in auto cad is 2 purple or blue lines and in Revit it is an actual object with several or many different properties to it and I think that has been the most challenging adoption in the progress. I think the biggest challenge has been understanding from every level in the process, so from the designer who is drafting it to the director who is coordinating the work that's been the biggest challenge.

CC: So if you were to think of maybe a PRS scheme you have used data with how did that go from feasibility to whatever stage you're at now?

LP: Measuring data points all the way through requires a complete restructuring of what our services are as an architect and this is something that we have been talking about internally. It's basically doing the quantity surveyors job and it isn't just something we can incorporate into our work flow without any additional risk. What we would do is we are incorporating data drops into our programme so we don't have people asking for random things so we have incorporated a certain design and data issue that work for the timeline and the client and everybody else on the team. Does that answer the question?

CC: So the questions I have here are related to the RIBA stages of work which I have in the background but I think it is best to have a more flowing conversation because these were structured for someone that was closely working to them. So I have a question on each stage to establish a sort of time line.

LP: Okay, so that's an interesting break down because from that point of view we're seeing a whole breakdown of the stages because you're making stage 4 decisions at stage 0 and so the whole RIBA workflow stages were finding don't fit to some degree. When you're designing with data and you have it all up front, especially with mature clients and in sectors where there is a lot of information we can input that data at stage 0 because we have that information. So what used to be a decision that got made a year into the process, were making that decision at feasibility stage, so it kind of flips the whole thing on its head a little bit. That's the other struggle from a fee and services point of view that we see, in our clients conversations, that they expect us to be making these decisions early but then don't think about the service structure consequences. All of the decisions now are front loaded which didn't use to be the case. I think that's probably the biggest thing about stages that there are no lines anymore between them, and that's the whole point of designing a system is that you're whole model is more agile.

CC: I know you're saying you are flipping stages because you're using more data, do you have an example of how this changed a project. So, if you're brining in stage 4 technical information into stage 0 how does that affect the rest of the project?

LP: I think you're just moving risk around and from a cost point of view how much contingency and where the risk sits, so a very simple example on a residential scheme is the thickness of a demising wall. We know from previous projects generally where that's going to land, we know what the difference is going to be based on difference construction types. So that can be a 170mm wall or that could be 220mm or if you're looking at modular construction it might be 300mm, we make that decision in feasibility. That affects how you set out a building, that affects the size of the units, that affects everything and because we're reporting on areas very early in the project that has ramifications on the whole process. We need to make a decision on that early and its more about getting across that decision making process to the client and making sure the whole team understands the decision behind that process so that you know where to allocate the risk. So before, if you allocated the risk in terms of say we decided to go with a British gypsum wall then you know from a procurement point of view that you're going to be limited to certain types of wall systems. I think it's just about making the best decisions that you possibly can at every stage and because you have all of this data and information it allows us to make more informed decisions early on in the process.

CC: A couple of questions before we start to finish up, unless of course you have anything else that might be quite insightful is what have you found has always been the most repetitive task? If there was a part that you could say I would like this automated because this is really repetitive and we don't need to do it.

LP: Probably a lot of that has been inputs and outputs so things like schedules would be the biggest one, so were now automating workflows directs from Revit to Excel and vice versa which saves us a lot of time. Obviously human error then becomes lower because you don't have to worry about translating data from one program to another. We do find that we then spend that time analysing and making that that what get pushed out makes sense and that it's reporting the way that we expected it to report.

CC: What do you think the next push for technology and design might be?

LP: Organisation is definitely a big factor, anything can be automated right now but I think the biggest leap is getting the structure to push things from different programmes and I think that's all possible. I think the problem everybody with data is facing is how you get the data organised in a format that is legible across many disorganised data sets. The challenge that we have is to get the inputting data organised and then you can do whatever you need to do with it. Anything that's repetitive is probably going to be automated in the future but there is a big distinction between what's automated and what a computational design problem is with parametric sitting somewhere in the middle. Automation is what you can put in to a parametric model and a computational design problem is probably the most challenging, what you need to set up a computational solver. That would be something like generating a mass, or generating an arrangement of spaces that has the most value so those are some of the things were looking at computational design to solve.

CC: So these interviews are going to help me decide what part to put through into a system. If you were to think of a project that you've linked p to scripts, how does a project go through the different programmes and what is the process you take to work with data flow models?

LP: Yeah, I think there's probably a bit of a road map there because there's BIM and modelling with objects and then you're slowly moving towards parametric model and once you've got that worked out you can do a computational design model. A lot of it is designing the software stack and understanding how everything goes through each different work flow. That is something that has come on in leaps and bounds recently and being able to move things from program to program is much easier.

In the early stages we use the most variety of programmes such as Rhino and Sketchup, then that will get pushed into Revit and once it's in Revit we are using Dynamo scripts to measure different parts of the model. So right now, different pieces have different scripts but ideally we are working towards having one model working on one several scripts rather than just parts of our model being parametric. We're trying to move to a fully parametric building and that's the challenge which is definitely possible.

APPENDIX 4

A conversation with Jeff Kahane surrounding the role of an Architect and the RIBA stages of work

14th February, 2018

CC: [Presenting thesis abstract for Jeff to read prior to interview]

CC: The first question I have is focused around when you meet a client, RIBA stage 0 is identifying the brief and the client, when you receive a brief from a client can you describe to me the steps you would take to develop the project objectives and how you develop the initial program.

JK: Well, all the work we do at the moment is for private residential clients and that's not through our choosing it's simply what we get. The private clients usually haven't done it before so the brief may be quite nebulous and tentative or it may be quite specific and completely unrealistic sometimes. Sometimes if it's completely unrealistic we have a professional duty to say to a client that it isn't going to work and it's about scaling it back to meet the funding. I try and go in quite slowly, even giving a client a fee proposal I aim not to rush it, with the clients we get you can usually have two or three meetings and you begin to get a feeling of what you should recommend to them. One thing that does come up often is if their funds are tight that one way to save money is not to have the architect running the job on site. We tend to offer that as a flexible thing to clients and offer two fee proposals to meet that and we can come out on jobs with limited time on site.

Another thing is about just trying to explain the timescales for jobs and to understand the type of a work they are expecting, for example if they are looking for 3D visuals during a project it adds time on to the design process. We do offer a measured survey of the house but we often recommend they get a surveyor in as the laser technology now does a much better and quicker job and if we do it it's an additional fee. Those are the typical things we tend to do when starting a job.

CC: So how long does that typically take you, a couple of weeks?

JK: I'd say around 2, sometimes during that two weeks I tend to send them information, perhaps precedents in the local area or aerial views and things to give them as much information as possible.

CC: I have a hypothetical site here, it is a large site and a site I am familiar with as it is my current project site which makes it much easier to ask questions on and understand answers. The next stage of my questions looks at the RIBA stage 1 and uses this site, so if you had this site for a project and your client was government based can you describe how you would approach this stage of a project? Or if you have a project that is live at the moment we can use that?

JK: We have a project that might become live or might not, there is a site in London that we have adjacent to a developed site that the client would like you see how many houses they can get on the site. That is one of the biggest sites we have at the moment, I started with google earth maps and worked out the size of it scaled with the size of cars, very primitive as the client didn't want to pay for an ordinance survey. I worked just at a small scale working out how many units I can get, wrote a report and analysed that part of London in terms of its transport links etc. I try to spend in all about 2 or 3 working days on it and pointed out to him potential problems and opportunities for example there is a listed building near the site. I gave him a list of the number of units and the possible risks with complaints from residents equally matched by the fact councils are under an obligation to approve as many new dwellings per year. Does that answer the question?

CC: Absolutely, I am really interested in planning the working process so that I can start to pull it apart and see where we can allow automation to enter the profession and benefit us. So would you say at the point are there any tasks that you think are repetitive, things that you think aren't the best use of time? Do you find it is usually in the early stages or are there any other stages throughout the project?

JK: I can't think of anything right at the beginning, its more to do with juggling orientation and loss of daylight or views and parking, privacy etc. and it's tough. I am not against it but I don't know how it would work, I am not against it working I just don't see a way it could. Ai is developing and automation is developing so fast though it could be completely different in 10 years' time. We've recently upgraded our programmes to vector works 16 and there's a big difference with the speed of which things can be produced now and it's amazing. For architects there's one thing with automation and CNC cutters that are amazing for design and now with technology you can produce the cad information, send it to a fabricator and you can get their prices which means complexity costs so much less. That point of being able to send drawings to a fabricator and being able to do complexity at no extra cost is wonderful. Apart from that, how automation is impacting in other ways on the design process I am not sure. I always take the view that usually when technological developments are made it is just another tool in your toolbox and a carpenter doesn't throw the ordinary screw driver because he has one he can fit onto his drill. The number of tools simply increases and you have more tools at your disposal, and whilst some things with technology replace others but I quite like working with physical models and cad models with renders and without.

CC: At this point how do you share the work between yourself and the rest of the team?

JK: I tend to like to have control of all the projects, we have about 15 jobs live at the moment, probably about 5 or 6 are in the design stage and I want to know what is going on in every job and I like to read every email that goes out. There are of course offices of a size where you can't do that but I like to keep a check of everything that goes on in the office. That way of working only works in a small office, there's about 5 of us in the office at the moment but it does mean that the office has a kind of ethos that every project hangs together.

CC: So say if we go back to a hypothetical site, I am thinking now of developed design and technical design what tends to be the working pattern throughout this stage? When do you tend to bring in consultants for certain things and what type of relationship do you have with them?

JK: At this small scale of work mainly you just work with the structural engineer, the party wall surveyors and the mechanical and electrical engineers. Often we can work with the lighting consultants and the plumbers because at the small scale we work at they tend to have the knowledge to work alongside us. Lighting is one of those things that is becoming more complex with the transition to LED lights and sometimes we do have a lighting consultant on board. We get the engineers in early and we have a good working relationship with them, often you can get advice before you do a fee proposal for some things. The other key member of the team is the building control officer, we get them in really early and work with them through the building regulations and they are monitored by inspectors to comply with the council. If it's a bigger site you would need to bring in a lot more people as you have to structure it in a completely different way and things go quite differently.

CC: I have a couple of questions on tender and construction, so say if you were putting together a tender pack how long does that typically take you and how much do you need to have ready before you go on site? What tends to happen through these stages?

JK: If I am contacted by potential clients I tend to go and meet them and see their house or their site and I tend to say to them that it's never less than 6 months between appointing your architect and the first shovel going into the ground if you need planning permission. It's usually then a month and a half to get a planning application in, the council has 8 weeks to make a decision and if it's a big job it will usually go to committee which adds another month. Whilst it's in for planning I tell the clients they can ask us to start on site but it is a risk because if they don't get planning you have to pay everyone's fees. It's never less than a month to do a small residential job at planning stage, usually for tender it's a competitive negotiation and that period itself is usually 3 to 4 weeks officially. Once you have tender the client works it with their budget and arranges a time for the builder to start on site which is usually in a few weeks and that process as a whole usually takes you to around 6 months.

CC: What do you think about the end life cycle of a project, is there any more you'd like to do after a project has been built? It is interesting how we finish a building and then a lot of the time only ever see it again in photographs.

JK: Firstly there's the defect liability period which is 3 months on small projects, 6 months on bigger ones and 12 months on some so you go back for that and see how it's performing. We also like to go back and get photographs if the client doesn't want to keep it confidential. In terms of energy monitoring and performance it is something that is happening more and more and it's needed because there's a lot of claims about how energy efficient buildings are. There are some firms who go back and do a lot of performance monitoring but for us I think it's good to keep in touch with your client to see how it's working for them to build a good working relationship.

APPENDIX 5

A conversation on the importance of spatial and social intelligence within the public realm with William Beeston, Publcia

26th March, 2018

CC: [presented abstract to will prior to first questions]

CC: The first questions I have on here is stage 0, one of the main things I was looking to get from that question is if there is any set way of working when you get a brief? A follow on from that is does it change if you know the client, do you do less in that stage with a client you've never met or not?

WB: That's what is kind of interesting with Publica is that the bulk of our work is helping the client to find a brief. They may have come to us with a development that is close to going to planning but they have realised that the key element, the public realm isn't going to get past. They come to us retrospectively and we do a lot of site surveys to understand the place to help them develop the brief. That is out body of work at that point and sometimes those projects get carried through to the further stages, generally concept design and then it will get passed on to a landscape architect or local authority. It is a service that isn't as traditional as others and often developers don't realise how important it is to get that right and how valuable that will be to their property.

CC: I can see in a way why Euan suggested you would be a good person to talk to, one of my hypothesis is that if some things can be automated other parts of the design process like how people interact with space will be a lot more fundamental in a project. I feel like if we can be savvy enough with designers to understand how people interact with space a lot more, our job can't be automated.

WB: That's interesting because there's a lot of talk about architects being relegated to the all-round builder, or relegated to thinking about space. That's fine, that is what I think we should be doing and the value of that should be bigger.

CC: For the next question I was intending to propose something hypothetical but I found it wasn't a useful as I thought it would be and it is more useful to get you to think about a client you have now and sort of go through your work process.

WB: For us this stage is all about getting a really comprehensive understanding of the place and the context of whether it's a masterplan or a large public realm project. We define an area around the site that goes beyond the red line that is set by the client so we can really understand the context. We do a set of surveys that focus with being on site, we start with a set of land use drawings mapping out on site exactly what we see on the ground and we have defined our own categories rather than work with the town and country act. We find them more useful for defining place but in a way that takes a lot of time on site and that time is spent trying to find nuances and particular things that could define a new set of surveys for that site.

CC: Do you tend to go to site to do this or is it desktop?

WB: Yes, it's very much a combination of desktop looking at history and sorts but primarily the key thing to our methodology is spending a lot of time on site. Typically a survey team would spend a week spread over a month on site because we think that is really important in terms of understanding a place in order to create a robust brief for whatever is being designed. It is a very kind of analogue approach, it is all about the particularity of a place. There is technology now that can use facial recognition to analyse a site and even look at body language to understand how people react to a site. I think using that to simply churn out a data set on a site is unrealistic on its own but we do use often, if were working with TFL for example, their gate counts. They have a lot of information about who's coming in to a station and what peak times or numbers of people are there. That is really useful but it's not useful if you don't go to site and look at what's going on.

CC: Yeah, it's sort of quite separated from the two, have you heard of Senseable Lab? It's a research lab that look at big data sets that simulate how people move through space and whilst they are really useful analytical tools I still see it as working with an architect and not on its own.

WB: We quite often include work from SpaceSyntax because they have a lot of computer methodologies for understanding place but we put it in there because clients like it and it's a hard data in combination with our stuff that is experiential.

CC: Do you do anything in the other RIBA stages, I know you said sometimes you get to post planning but how far do you tend to take it?

WB: We usually work to concept design, sometimes to stage 4 but not really because we don't have the liability to actually guarantee our design so we think to that stage but advise the client to get engineers.

CC: I know you said before that you'd developed your own set way of working, did we touch on that or not? I thought that was really interesting.

WB: So that is in stage 1 which is our survey methodology, that's very much when we started 7 years ago nobody was doing that sort of work and understanding place was kind of tokenistic. You'd do a kind of public realm design and spend a day on site taking some photos but it came from one project in a way that was an oversight development. There was a project that the council weren't happy with the proposal of and we realised that you needed to understand the public realm. We put together this proposal and decided we were going to do a huge part on the public realm and kind of developed a loose methodology whilst we were doing that project. It was decided that land use was the first thing to understand, from doing that spent a good time on site realising it was a really good thing to do. Which kind of went on to map all the frontages, whether they are blank or active. Mapping all the public furniture such as bike racks and looking at how people move around the area. A big secondary thing we do is looking at precedents and similar places that we think work well with similar places that we think don't work well. Say if were talking about a square, we would talk about the frontages and put together some precedents for that to talk about how well they work.

CC: I'm interested, hat did you do before you worked at Publica?

WB: I was a graphic designer, I worked a lot with architects and that's kind of how I ended up studying architecture. I wanted to get involved with the other side of it all and I didn't want to just be designing signs. I saw that architecture was massive and there was so much to it.

CC: One of the things I'm interested in is, do you think there is any part of the work flow that can be automated. Especially of an architect, is there something that you think we do that doesn't need to be done as much so we can focus on more?

WB: That's a good question, I think you've kind of touched upon the fact that there are really important things that we do, that if other parts of our job were automated they would come forward. We are looking at GIS at the moment in terms of survey, it's a kind of mapping software and apparently a lot of what we can do - rather than taking notes and putting it onto site in illustrator it can be already set up and use an iPad.

CC: In respect to that, if there are things as you say, that are really important to what we do, what kind of things do you think aren't as important?

WB: I think we spend a lot of time on larger project detailing things and reinventing things that don't need as much thought, that doesn't help because clients and developers think architects are just designing facades. I think it should be more about designing spaces and I don't think many people get that, the nuance of space in particular public spaces. It's often the last thing people think is important and the last thing people presume architects think is important because so much time is spent detailing facades. It's more about what opens at ground levels and the light that comes in to a space, if buildings were all churned out of an algorithm you wouldn't be able to engage with them.

The built environment is a product of human activity and creativity, all kind of human behaviour and desire is tied up into it. I wonder if it all gets churned out of a 3D printer that it could become kind of soulless.

APPENDIX 6

Interview Questions

Overview: The technological developments of the near future have undoubted potential to affect the way we work as architects, in order to remain the lead design role of construction we need to understand how the role will change. In order to gain a greater understanding of the areas in which the role could change, this set of thesis interviews aims to map the current working pattern of an architect.

Aims: The purpose of this questionnaire is to gather in depth and varied data in order to draw a detailed timeline mapping the job of an architect.

NB. These questions were varied and verbally edited to fit the specialism of each interviewee.

Question 1 – RIBA Stage 0. Strategic Definition [A]

CC: I want to start out by discussing the RIBA Stage 0, its aim is to identify the strategic brief and business case of the client. When receiving a brief from a client, describe to me the steps you take to develop the project objectives and programme. How does the way you establish this vary from a client you have an existing relationship with, to say a client you have just met following a competition win?

Question 2 – RIBA Stage 1. Preparation and Brief [B]

CC: Over the next two questions I want to propose a hypothetical brief and site to get a better understanding of the early stages of a project. Imagine you have a client, government based, who has a 68m2/6.81-hectare site he/she would like to develop [introduce the Turin site photograph]. Whilst I have worked on feasibility studies and site research both in practice and in my studies I have little experience in the managerial tasks and wider range of Stage 1 tasks carried out during this stage. Describe to me how you would approach this stage and what key areas you typically address at this time. Can we draft a quick programme?

Question 3 – RIBA Stage 2. Concept Design [C]

CC: Referring back to my site photograph I want to move on to the concept design stage, if I ask you to look at this site, tell me what the first things you would do when beginning a concept design and what do you take into consideration? How do you tackle the site, does it vary in terms of the scope/ client? During this design stage what would you need to have completed before you can move to developed design?

Question 4 – RIBA Stage 3. Developed Design [D]
CC: Moving into the RIBA stage 4 (or stage D) the design development

stage expects the architects to have outlined project strategies, structural design and cost information. What tends to be the working pattern during this stage and what members of the team tend to deal with what?

Question 5 – RIBA Stage 4. Technical Design [E]

CC: I briefly worked at this stage of the design during my work placement at Part 1, I noticed during this time the architects often worked alongside consultants. Is this the case for you and who would you usually need to consult and why? Describe to me the tasks you tend to deal with during this stage.
The old RIBA plan of work contained a Pre-Construction phase with production information, tender documentation and tender action. Now this is redistributed what do you need to have completed before you move to the construction phase?

Question 6 – RIBA Stage 5 Construction [J]

CC: If it is easier to refer back to the hypothetical project I mentioned earlier, or perhaps you have a project on site at the moment can you describe to me the first stages of the construction phase.
During my part 1 placement I often shadowed in on-site meetings but as the project was a large scale masterplan my role was quite small in regards to responsibility at this stage. What tasks does the architect often undertake during this phase, describe to me the content of the meetings and the relationship between the contractor and the architects.

Question 7 – RIBA Stage 6. Handover and Close Out [K]

CC: At this stage of the RIBA plan of work there is the least prescribed tasks, I imagine however this is not the case. What do you tend to deal with at the hand over stage and what kind of things do you need to overcome before you move forward?

Question 8 – RIBA Stage 7. In Use [L]

CC: Once the building is in use what responsibilities do you have as the architect? What tasks do you have post construction and is there anything you do during its life cycle following?

Question 9 – Opinion

CC: Now we have looked at all the stages of design and construction I am interested to know a bit about how you feel being the lead designer and architect of a project. Do you set yourself goals to accomplish outside of the programme, for example personal goals? What part of the process do you find the most rewarding and why would you say it is? Do you think there is anything that happens during a project programme that hinders the aspirations of the designer?

Question 10 – Automation

CC: As you know my thesis is exploring the topic of automation, what would you say is the most repetitive task you do on a daily basis? Is there any part of the job you think could be automated, allowing you do undertake tasks that could be more rewarding to the finished architecture? What about things that you really think couldn’t be automated?

LIST OF FIGURES

Appendix Figures

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