

# Analogue Automation

## *The Gateway Pavilion for Headland Sculpture on the Gulf*

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*The Waiheke Gateway Pavilion, designed by Stevens Lawson Architects originally for the 2010 New Zealand Venice Biennale Pavilion, was brought to fruition for the 2017 Headland Sculpture on the Gulf Sculpture trail by students from Unitec Institute of Technology. The cross disciplinary team comprised of students from architecture and construction disciplines working in conjunction with a team of industry professionals including architects, engineers, construction managers, project managers, and lecturers to bring the designed structure, an irregular spiral shape, to completion. The structure is made up of 261 unique glulam beams, to be digitally cut using computer numerical control (CNC) process. However, due to a malfunction with the institutions in-house CNC machine, an alternative hand-cut workflow approach had to be pursued requiring integration of both digital and analogue construction methods. The digitally encoded data was extracted and transferred into shop drawings and assembly diagrams for the fabrication and construction stages of design. Accessibility to the original 3D modelling software was always needed during the construction stages to provide clarity to the copious amounts of information that was transferred into print paper form. Although this design to fabrication project was challenging, the outcome was received as a triumph amongst the architecture community.*

**Keywords:** *Digital fabrication, workflow, rapid prototyping, representation, pedagogy*

### INTRODUCTION

This paper examines the integrated processes between digital fabrication and analogue construction methods used to produce a complex, spiralling glulam beam structure, the 'Gateway Pavilion' for the Headland Sculpture on the Gulf arts festival. The Waiheke Gateway Pavilion has already been recognised within local architectural journals, lifestyle

magazines and won local awards. The cross disciplinary team of students from Unitec Institute of Technology's architecture and construction departments working in conjunction with Stevens Lawson Architects, engineers Holmes Consulting and building specialist Ebert Construction.

The use of powerful software to design a complex architectural product is increasingly becoming a

popular trend amongst young practitioners (Mamou-Mani and Burgess, 2015). When complex architectural forms are pursued, a set of challenges need to be overcome before any concept can be realised, such as establishing a workflow that accommodates for all possibilities within the project (Garber, 2017). The Waiheke Gateway Pavilion is no exception. The architects design required material and production knowledge to be embedded into the developed design phase before any fabrication could take place. The benefits of using a digital software supports both students and professionals in a simple workflow aimed to realise different levels of complexity of design and fabrication of architecture (Aish, 2003).

The original manufacturing method to be employed to create the components for the 'Gateway Pavilion' was to utilise an automated Computer Numerical Control (CNC) process to fabricate elements that could be subsequently assembled by students using basic tools such as spanners and drills. The strategy to extract encoded data from a computer generated model and to input it into automated fabrication equipment to produce a high precision and low tolerance structure was considered to be an easy and attainable task, particularly given that the project had to be delivered within a limited time frame. We were confident that this method would be attainable given previous experience with projects such as Chris Moller's Click-raft, a crafted construction system which utilises CNC machining to form custom structural elements within the design (Moller, 2012). A major part of the project was to communicate information for fabrication and assembly between the architecture and construction disciplines. This required development of a system that was easily understandable and graphical in nature to avoid errors. Even though the Gateway Pavilion's form appeared complex with over 261 glulam and 51 rough sawn unique parts, it was a deceptively simple fabrication and assembly process when file to factory fabrication methods are employed.

The following paper describes an architectural student's perspective with the aim of providing an in-

sight into the tension between integrated digital and analogue fabrication approaches throughout the duration of this project. The first portion of the paper will examine the problem that was presented to the team of students. To follow, a discussion into the methodology and findings of the project in regards to an integrated digital and analogue approach. To conclude, as a response to the findings a critique into the pedagogical learning outcomes within this project will be discussed in relation to the cross pollination of learning between the construction and architectural industries.

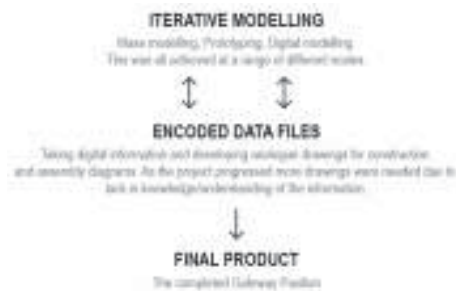
## PROBLEM

To realise the concept of the Waiheke Gateway Pavilion, digital tools were employed to accurately represent and to extract those elements for fabrication purposes. Although this could be done by hand, digital tools provided us with opportunities for greater exploration of the shape. Digital and analogue fabrication methods are both a generative medium that hold their own restraints and allow for different possibilities such as narrowing the gap between the representation of architectural information and building (Iwamoto, 2009). In the instance of the Waiheke Gateway Pavilion, this narrowing of the gap allowed for the efficient production (and reproduction) of the many necessary schematic and shop drawings required to fabricate the numerous individual building elements. Digital tools facilitated efficient transfer of information between architectural, engineering, and construction disciplines. The digital model was used to make aesthetic and structural decisions as well as being used for representation for fabrication and construction purposes.

The original plan to implement a file to factory process, where the digital data could be easily translated into a language to run the institutes CNC router (Iwamoto, 2009) became unworkable due to a malfunction, meant a new design-fabrication-assembly workflow had to be developed which required a construction workflow based on hand production. This had to be developed, tested and implemented within

three weeks. A workflow based on hand production required several digital to print paper processes to be performed to inform construction.

Figure 1  
The iterative design-to-build process utilized by the team of students



This caused problems due to various skill levels within the project team of students. Architectural students were prepared for file to factory processes and otherwise are trained in producing scale drawings that demonstrate design intent, not highly detailed shop drawings. The construction students were at the beginning of their training with limited experience in reading conventional architectural drawings. Added to this, the construction students are being trained in an industry reliant upon pre-assembled framing as opposed to developing skills with tools for elaborate non-standard structures. As students were coming from such a varied background of skill and experience, the method to be developed needed to be simple, clear, and efficient.

**Time frame**

The entire project spanned over three months, between late October 2016 till late January 2017. The detail design and scaled prototyping produced by the architectural students, engineers and project architects was performed in the initial two months of the project, this is when the malfunction of the CNC machine happened. The last month consisted of fabricating components at the institutes workshop before the erection of the Waiheke Gateway Pavilion on-site in early January, leading to completion on-site for the 24th January 2017.

Figure 2  
1:10 scale model used to visualize elements that would otherwise be missed within the digital model.

**Task**

Working outside of the standard industry for both the construction and architectural students was a new experience, therefore information derived from software had to meet the following criteria; firstly to produce shop drawings from digital data to allow student fabricators to manufacture components with accuracy. Secondly to convey all the required information needed for hand assembly. This portion of the process was the most difficult, as the structure is reciprocal system and required a holistic approach for overall understanding for all parties involved. Furthermore to create a labeling and tracking system to ensure the project is assembled correctly. Normally this would be a simple task within an automated process but due to the malfunction of the CNC machine this process required greater attention. As each component was unique and needed to be labeling correctly in order to be cut and drilled accurately. The designing of a production line process was to created to ensure all components were produced efficiently. This required deadlines to be set, with targets to met daily. Lastly, if one of these processes fails, all others will as well as they are all intrinsically linked.



**METHODOLOGY**

The development of a design through an iterative process is a staple within any design process and is a fundamental element with architectural practice. The architectural design process is not so dissimilar to the iterative progress within a science experiment in order to resolve problems (Lucas, 2016). Architects must work with engineering and construction consultants to break down design ideas into manage-

able portions. As a result, numerous scenarios can be tested to allow for fewer questions and uncertainties to arise during construction (Anderson and Anderson, 2006). Modelling conceptual ideas in 3D digital space provides an environment for information to be readily available at the discretion of designers and fabricators fingertips. This allows for the embedded data to be used for scale prototyping, visualisations, quantity surveying, and allow for augmentation for design development (Iwamoto, 2009).

There is no doubt that architectural software today can allow for successive design iterations efficiently. The instant visualisations is evolving and fast becoming a part of the every design process (Sheil, 2005). The obvious advantages of working within a digital environment over an analogue hand process is with how information can be manipulated, transferred and replicated with ease (Dunn, 2012). For example, if an architect needed to change a hand drawn design, a workflow to amend it would entail a laborious process to redraw it. Again, if conceptual model was required for spatial validation, a designer cannot simply extract data from a virtual model and print it via a laser cutter. They must be physically measured, drawn, hand cut and checked before any final assembly can be pursued. (see Figure 1)

## FINDINGS

The development of a conceptual model or hand drawing that needs be transferred from a digital environment to physical product requires several processes to take place. To begin, a discussion into the design development phase by the architect will be discussed. This will be followed by a discussion into the structural and production development of the project conducted by architectural students, project architects and engineers. A reflection into the effectiveness of full scale prototyping with the absence of automation will follow, before concluding with a brief discussion of the implementation of the assembly on-site.

### **The design development phase**

Information and understanding with complex forms can be difficult to describe with only two-dimensional paper representation. To overcome such issues there is a need for a representation to provide adequate conceptual information not only for clients, but to fabricators and engineers (Allen, 2009). Stevens Lawson Architects original concept for the Waiheke Gateway Pavilion was not generated digitally but was realised through a narrative. This narrative was described as a whare becoming a landscape and returning back to a whare. A whare is the Maori word for house or hut. The realisation of this concept was assisted through digital software where further design iterations took place.



Figure 3  
1:1 Detail  
Prototype: This was used to test for tolerances, check connection details, gauge material aesthetics before material was ordered.

### **The structural and production development**

To ensure the project came to completion on time, a number of processes had to first be established to enable students with varying levels of experience to produce a highly refined outcome. The major component of this process was to establish clear directions for fabrication and then assembly. The computer generated model provided to the students by the architects was a massing form. It needed to be tinkered, transformed, and refined in order to be useful for manufacturing purposes.



Figure 4  
1:1 scale prototype of six portal frames on-site at the Institutes workshop . This prototype was vital in the progression of the project.

The use of prototyping allowed for design, material, and assembly processes to be refined and quantified. Investment into rapid prototyping models and full scale mock-ups assisted to amend faults and miscalculations through the developed design process. Digital prototyping originally allowed for easy production of components. With the malfunction of the CNC router, digital technology was primarily used to create documentation to inform production.

component was unique in nature, with its own set of details and required location markers and diagrams for correct assembly. (see Figure 3)

**The effectiveness of full scale prototyping with the absence of automation**

The 1:1 scale prototyping for this project was used to form a viable construction/assembly method and was achieved by the erection of 6 spiraling portal frames at the institutes workshop. This prototyping was by far the most important as it highlighted problems in material lengths, and time frame of the erection process. The need for diagrams to aid in the visualisation for projects and their realisation is key to disseminate information for fabrication (Allen, 2009). This concept is highlighted within the prototyping phases, as the original shop drawings needed to be heavily augmented to ensure the communication with entry level labour was understood. The fastest form of prototyping of digitally derived by print media is by augmenting and developing it by drawing over it by hand and pencil (Gage, 2012). (see Figure 4)

Simple excel forms were created to track. The process of translating the encoded data was ongoing throughout the fabrication and construction stages. This form of prototyping lead to multiple changes within the encoded data documentation. The amount of drawings increased to over 600 pages from the original set of 300 that was produced. For example, the bolt hole sizes and allocations. Originally they were designed with a small tolerance to allow for hand assembly. Prototyping at this stage showed that this allowance didn't work due to movement in the frame and miss-aligned edges. This wasn't picked up within earlier, scaled models and just goes to show the importance and value of a full-scale prototype prior to full fabrication and construction.

The notion of designers as builders (Kieran and Timberlake, 2004) is demonstrated in this project by the architecture students contributing to aspects such as quality assurance, quantity surveying, fabri-

Figure 5  
Architecture students doing quality assurance checks in the early stages on fabrication, to determine the correct information is being translated onto the glulam beams.



Representation via prototyping can be simplified by dividing it into three simple steps that allowed the iterative process to form discussion and decisions. The first prototype to be developed by the students was the creation of a 1:10 scale model (see figure 2). The purpose was to depict information visually that would otherwise be missed within a digital environment. It became an important model to explain the design and how it may be produced. Problems of tolerance, alignment and connection were discovered and quickly rectified through digital software.

Figure 6  
Beginning of assembly on-site, middle of January 2017



A 1:1 detail mock up was important to gauge material aesthetics, timber treatments, tolerances, and connection details to before supporting material was ordered. The malfunction of the CNC was discovered here and with that a new approach had to be defined through drawing representation for fabrication. Fortunately, the vector files required for CNC production where re-purposed to create shop drawings. As each

cation and assembly phases of the project. This was necessary in order to overcome problems that arose due to workflow changes. This project is a showcase of the outstanding skill, craft and knowledge that are key to achieving an integrated process in such a complex design and build. This project became a learning experience for the students involved as it showcased how having the required software on-site during fabrication and construction aided in the completion of the project. It allowed them to learn a new craft whether it was the architecture students learning how to fabricate their designs or construction students learning the importance of the design and documentation stages of a project. (see Figure 5)

### **On-site fabrication**

The time frame for the erection of the project was vital due to only having 2 weeks onsite to get the structure assembled and signed off by engineers to allow public access for the event. Although this data was directly extracted from reliable digital files there was still confusion on-site during the early phases of construction. This showed how valuable it was for all necessary people within the fabrication and assembly team to be involved throughout the prototyping processes. The workflow to communicate this information was then changed, an onsite computer with access to the original 3D model was then used to inform rather than rely on the information provided in the printed drawings. Powerful tablets today, can hold

all the information needed. It took one tablet, controlled by the senior architectural students to clear up any problems that may have occurred (Krygiel, 2010). (see Figure 6)

### **CROSS POLLINATION OF STUDENT LEARNING**

Even though the project represents complex design it is an advocate to the requirement for traditional skill, organisation and construction knowledge.

The disruptions within the project were frequent. A short project time frame, the complexities of the design, and the change of fabrication process contributed to some of this. However, the communication between multiple disciplines arose as a defining issue. It became apparent that in order for the completion of the Gateway to be successful the architectural students were required to be more involved as they served as a conduit between the digital and analogue realm, rather than just being observers on-site. This iterates the need for the student contractors and fabricators to understand digital mediums in order to resolve problems within complex builds.

### **Organisation**

The communication amongst the team members was resolved by allowing for three different integrated processes to be implemented into the workflow at the workshop and on-site. These three aspects all together would allow for easy and clear com-



Figure 7  
The Gateway  
Pavilion on-site for  
the Waiheke  
Headland Sculpture  
on the Gulf 2017

munication, allowing lecturers to organise students. Firstly, the creation of small cross-disciplinary units to take charge of particular tasks during fabrication and assembly on-site and at the factory. Secondly, each unit had five construction students to one architectural student in order for digital organisational information to be accessed and to finish, the skill, craft, and knowledge were all important in a particular person's ability to achieve certain goals and tasks within the time frame.

The architectural student's obsession for a beautiful assembled detail to ensure quality and craft was contrasted by construction students desire to produce at speed to meet deadlines. These contrasting approaches caused conflict amongst the team on-site, exacerbated at times through inexperience and time frame. There was a realisation by the architecture students that the most important skills they needed to contribute to the project were to present information and communicate their knowledge effectively to all team members, and to efficiently organise the project phases.

project at a scaled physical form (Burry and Burry, 2012). Many had not worked within a project that demanded so much prototyping as there were several different iterations with different approaches whether it be the design itself or trialing a method for the assembly.

There was great reluctance by construction students and building consultants at first to work beyond the drawings and to accept digital processes in conjunction with prototyping. Experience on their part dictated their opinion, which by all means is valid as local building practice do not tend to get the opportunity to prototype or build complex architectural forms (Krygiel, 2012). As the design programme progressed, acceptance and an understanding towards the need for such an approach developed.

The passion of the architecture students drove their desire and sacrifice to work beyond their required daily shifts from the outset. As a collective, they learnt that this practise was not initially shared by other disciplines within the project. By the end however, as the construction students became more a part of the design process they too demonstrated the desire to work long hours in order to successfully realise the project. An acceptance from the architecture students towards building at full scale is tough and takes a lot of energy from an individual which led to an unspoken respect by the end of the project between the two disciplines.

## CONCLUSION

This project highlight the value of employing iterative processes and how having an integrated workflow can achieve a successful outcome. In the case of the Waiheke Gateway Pavilion an iterative investigation was first required to find the most efficient approach to develop an alternative fabrication process. It became evident that for this project to be successful a greater understanding of other available construction processes was needed in order to explore comprehensive prototyping at different scales. This process was used to determine the appropriate fab-



Figure 8  
Left: Detail of spiraling connection Right: The Gateway Pavilion on-site for the Waiheke Headland Sculpture on the Gulf, Arts Festival opening night.

### *When digital production is not an option*

A project originally intended for digital fabrication had issues when produced in an analogue manor. Human error and tolerances became problem once the option of CNC machining was replaced by hand cutting and drilling. Prototyping throughout this project allowed for further understanding of how corner joints and detailed information was to be assembled at full scale. This understanding was not only to inform the architectural students, but to also aid professional industry personnel about the

rication assembly method onsite that would provide greatest efficiency in the short time frame. The Waiheke Gateway Pavilion project also highlights how complex bespoke builds benefit from access to digital information onsite. (see Figures 7 and 8)

Important learning experiences came with re-evaluating the project due to the need for analogue organisation; new skills and knowledge to be understood, acquired, and to be worked back into the design to fabrication process. Aspects on how best to integrate students from collaborating industries that tend to have conflicting purposes between the importance of design and the practicable needed to be negotiated. Overall this project was a learning experience not only for the architectural students that were involved from the designing and documentation stages, but also for the construction students that only joined in fabrication stages of the project. New skill levels have been achieved for the architecture students as they can now not only produce encoded data for digital production and a highly defined computer generated model, but can also create shop drawings that convey accurate information for the construction trades. In addition, the project has highlighted the value to bring closer the disciplines of design and construction in order to effect more collaborative working arrangements, greatly benefiting the final built outcome and contributing to clearer design, fabrication, and assembly processes.

In combining the available digital tools for communication, design development, analysis, and fabrication and assembly with analogue techniques, the Waiheke Gateway Pavilion developed an integrated process which resulted in a simple and efficient design, fabrication and assembly process to realise a complex spiraling shape.

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