

# The Role of Acoustical Design within Architectural Design in the Early Design Phase

O. Wright, N. Perkins, M. Donn, M. Halstead

**Abstract**—This research responded to anecdotal evidence that suggested inefficiencies within the Architect and Acoustician relationship may lead to ineffective acoustic design decisions. The acoustician spoken to believed that he was approached too late in the design phase. The approached architect valued acoustical qualities, yet, struggled to interpret common measurement parameters. The preliminary investigation of these opinions indicated a gap in the current New Zealand Architectural discourse and currently informs the creation of a 2016 Master of Architecture (Prof) thesis research. Little meaningful information about acoustic intervention in the early design phase could be found from past literature. In the information that was sourced, authors focus on software as an incorporation tool without investigating why the flaws in the relationship originally exist. To further explore this relationship, a survey was designed. It underwent three phases to ensure its consistency, and was delivered to a group of 51 acousticians from one international Acoustics company. The results were then separated between New Zealand and off-shore to identify trends. The survey results suggest that 75% of acousticians meet the architect less than 5 times per project. Instead of regular contact, a mediated method is adopted though a mix of telecommunication and written reports. Acousticians tend to be introduced later into New Zealand building project than the corresponding off-shore building. This delay corresponds to an increase in remedial action for each of the building types in the survey except Auditoria and Office Buildings. 31 participants have had their specifications challenged by an architect. Furthermore, 71% of the acousticians believe that architects do not have the knowledge to understand why the acoustic specifications are in place. The issues raised in this investigation align to the colloquial evidence expressed by the two consultants. It identifies a larger gap in the industry where acoustics is remedially treated rather than identified as a possible design driver. Further research through design is suggested to understand the role of acoustics within architectural design and potential tools for its inclusion during, not after, the design process.

**Keywords**—Architectural acoustics, early-design, interdisciplinary communication, remedial response.

## I. INTRODUCTION

**B**OTH architecture and acoustics address the common idea of human occupation of space. They both explore the quantifiable and intangible characteristics that inform the effect of a space on a user. However, anecdotal evidence has

suggested that inefficiencies within the Architect and Acoustician relationship may lead to ineffective acoustic design decision. This project evaluates these claims and assesses the need for change.

## II. THE ISSUE OF ACOUSTICAL DESIGN'S LACK OF INFLUENCE WITHIN ARCHITECTURAL DESIGN

This project examined the relationship between Architects and Acousticians within the early design phase to establish a situational diagnostic of the industry as a platform for a Master of Architecture (MArch) (Prof) thesis currently being completed in 2016. This project developed from conversations with both an acoustician and an architect about the role of acoustics within early architectural design. The acoustician believed that they were approached too late in the design phase due to a lack of value associated with the importance of acoustics by the client. The architect, however, did value the acoustician's insight, yet, when tested struggled to interpret common acoustic parameters.

It was hypothesised that the issues raised by these consultants extend beyond the two isolated people and into the building industry. This research project aimed to gain the necessary information to form conclusions that assess this hypothesis.

## III. THE USE OF SURVEY AS A RESEARCH TOOL

A survey research method allowed the 51 participants to provide qualitative and quantitative data, while preserving their anonymity. Groat and Wang suggest that surveying has a "capacity to take in the rich qualities of real-life...understanding the meanings and processes of people's activities and artifacts" [1]. This section examines the survey sample size, delivery method, and the creation of meaningful data.

### A. The Survey's Delivery Method and Implications

The survey was delivered to the employees of one acoustic company through an online survey tool. It was divided into seven sections, each addressing an individual component of the greater relationship between architects and acousticians. The sections provided a clear structure for both the survey and section five of this report.

The use of an online tool meant that the survey was easily distributed to anonymous users who answered the questions in their own environment. Qualtrics' manufacturers claim that it provides an easy to use and simply understood survey platform (Qualtrics). This simplicity is necessary as the users were not provided with any support when taking the survey

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and a complicated questionnaire could result in a lower response rate. Groat and Wang place an “emphasis on natural settings” stating that the objects of inquiry must not be removed from “venues that surround them in everyday life” [1]. As the survey could be taken anywhere, this project satisfied this condition.

#### B. Sample Size

The survey was posed to roughly 80 employees of one acoustics firm, 51 of whom completed it. However, some participants did not complete all of the questions so the sample size altered for each question. Participants had experience working within the building industry; however, due to the small sample size, their shared company experience, and the inconsistent sample size, the results of the survey cannot be extended to reflect the opinion wider of the acoustics industry.

### IV. COLLECTIVE INSIGHTS FROM THE ACOUSTICIANS

#### A. Demographic Representation

The data from the participants are representative of Acousticians in New Zealand, Australia, China and France.

62% of these participants work within New Zealand, with a further 30% working in Australia. These two geographical groups dominate the sample size with only a further 8% from other countries. Due to this low representation, the data were split into New Zealand and “Overseas”. However, this Overseas group is heavily represented by Australian participants.

Fig. 1 stresses key differences within the introduction of New Zealand and Australian Acousticians into a project. The comparison of six building types shows the difference in phase of introduction (horizontal) and necessary remedial work (vertical axis - with remedial action increasing with an increase in Y). The squares (New Zealand acousticians) and circles (Overseas acousticians) for each colour (building type) have a close proximity. The size of the point represents the level of variance within the data, with large points responding to a large amount of agreement within participants (and therefore a low Standard Deviation).

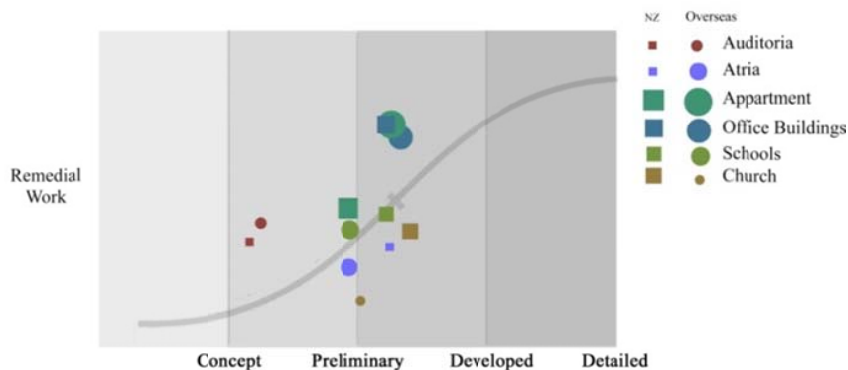


Fig. 1 Comparison of New Zealand and Overseas Remedial work and Introduction Phase

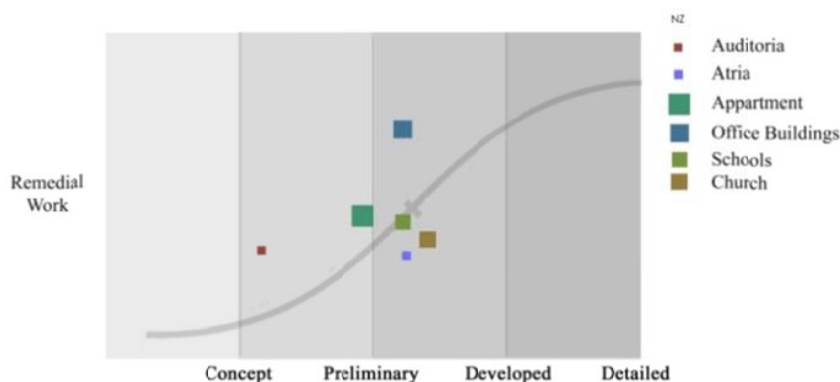


Fig. 2 Comparison of Remedial Work required and Introduction Phase for different Building Types within New Zealand

The New Zealand and Overseas data are highly comparable. However, a large difference can be noted between the New Zealand Apartment (green square) and Overseas apartment (green circle). Overseas apartments are introduced later in the concept design phase and result in a significantly higher

degree of remedial work (Fig. 1). This variation is of interest as it illustrates a difference within the industry, even within the Australasia area. These differences develop an understanding of New Zealand's Acoustics industry by placing it within the broader overseas context.

### B. Common Building Typology

There is a correlation between a later introduction of acoustics and a higher required amount of remedial work for all building types (Fig. 2). This remedial work costs significantly more than similar changes earlier within the design, illustrating a lack of acoustic influence. The buildings types with the most remedial action will be considered a master research proposal.

Auditoria (red square) illustrate an acoustics focus, with an early intervention and minimal remedial work required (Fig. 2). This result is logical, as acoustics is a key deliverable so emphasis is provided on an acoustician's involvement early. However, the result shows a large degree of variance (Standard deviation) for the amount of remedial work required. This is unexpected, yet, could be explained by a range within the auditoria typology or within the severity of what constitutes "remedial work".

Office buildings tend to require a large amount of remedial work and acousticians are introduced late within the preliminary/development phase. The office building reading has a significantly higher amount of remedial work in comparison to any other building type. This action suggests that there is an inefficiently occurring within the design, with the remedial changes costing the client significantly. This phase was one of the latest presented by this report and suggests that less of an emphasis is placed upon achieving quality acoustic treatment within the design.

A comparison of auditoria (designed around the importance of acoustics) and office buildings (designed with other non-

acoustic focuses) illustrates a connection between the degree of remedial work and the phase that the acoustician was introduced into the design.

### C. Assessing the Need for Change

This section examined the severity of the remedial and delayed work that a master research proposal could address (Fig. 3). Fig. 3 illustrates the percentage of projects that require remedial work due to one of four scenarios; no acoustic consultation, it arriving too late, it being ignored, or the late consultation causing delays.

The majority of remedial action is caused by no acoustic consultation. Most of the readings are positioned around the centre of the graph, indicating a spread of results. However, two spikes (dark blue and green) represent consensus from the participants. The "no consultation" (dark blue) spike indicates that 11 acousticians believe that more than 60% of their remedial projects occur with no prior consultation. The spike is over twice the size of the other results, increasing its significance. The green spike represents the "delay" scenario with 10 acousticians believing that 30% of their projects incur a delay because they are approached too late in the design phase. Both percentages imply significant impact on the project due to the lack of acoustical influence from the early design stage. These finding suggest that this topic requires further research because it addresses a current issue within the industry.

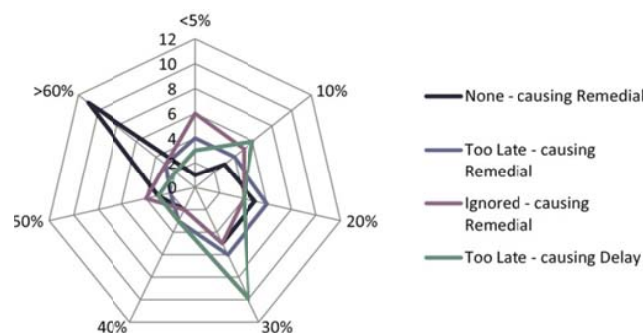


Fig. 3 The Context of Acoustical Input into the Design

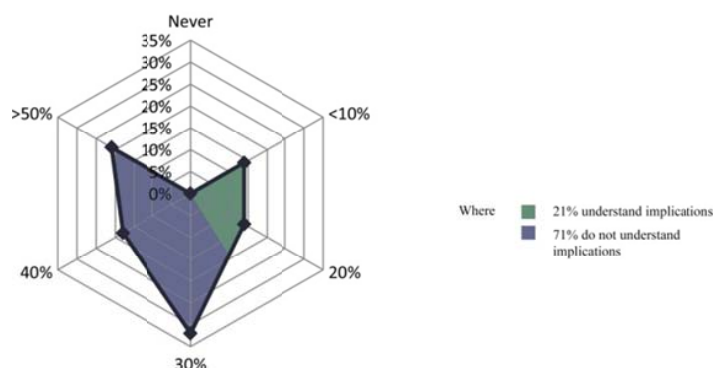


Fig. 4 A "Pie" percentage of Architect's understanding of Acoustic Reasoning Overlaid with a Radar-Plot of their likelihood to challenge

#### D. Understanding Architects

This section compared the perceived understanding of architects, against the likelihood for them to challenge the suggestions of the acoustician. The premise is that if one has a high level of understanding, then they are more equipped to challenge the specifications of the consultant. However, Fig. 4 indicates that despite challenging acoustician's specifications, 71% of participants believe that architects do not understand the specification's implications.

All of the 31 acousticians examined said that they had been challenged by an architect, with the mode being 30% of the time. Acousticians commented by saying that "being challenged is OK if it is for the purpose of testing the reasoning, but where it is to 'pick holes' then its (sic) unhelpful". The left hand side of Fig. 4, representing the high percentages of challenges, has a larger area than the right hand side, indicating a weighting towards the higher percentages of challenges.

Acousticians involved in the survey suggest that, generally, architects do not understand acoustical ratings and parameters, physics principles and differences between absorptive and insulation materials. Architects appear to focus on what has worked on previous projects without grasping that each project is individual. However, Acousticians state that "architects are not experts in acoustics so they are unlikely to understand the full context of our recommendations. It's our job to explain". This comment illustrates that a master research project should engage an acoustician to provide

insight into the individual elements of the design, rather than making assumptions based from previous design precedents.

#### E. Assessing Communication Mediums

This section examined the communication methods used by acousticians, informing the methods implement within the research project. The majority of acousticians use a mix between verbal and written methods (Fig. 5). This result is logical as it confirmed colloquial evidence towards a mix between telephone conversations and written reports.

When examining verbal communication it can be seen that 75% of acousticians meet the architect less than 5 times/project (Fig. 5). This lack of face-to-face communication was surprising as the use of an external medium (such as telephone) can lead to misunderstandings and a lack of clarity. This lack of contact could be an influence on the lack of communication between the two disciplines.

When communicating in writing, acousticians believe that diagrams are the most effective mode for communicating ideas to an architect (Fig. 5). This makes sense as diagrams are used frequently within the early design phase of the architectural discipline to quickly communicate multiple design options. This shared use of diagrams implies that Architects and Acousticians should be able to communicate during the early design phase. A mixture of verbal and written communication, with an emphasis on diagramming as a design methodology will implement in the research project. However, as diagrams simplify reality into signs and symbols, it must be noted that the meaning of the elements can get lost.

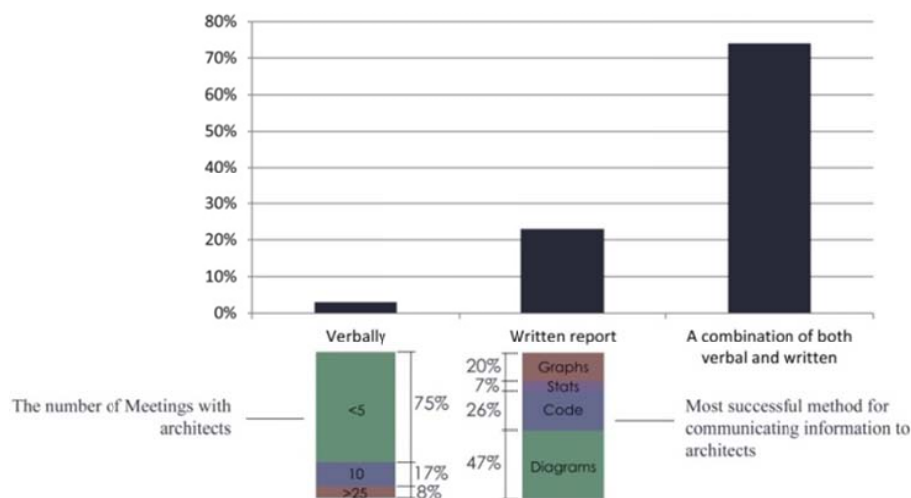


Fig. 5 Assessing Communication Methods

#### V. IMPLICATIONS FOR THE SURVEY

The results suggest that Architects and Acousticians do not meet regularly throughout the design phases. When communicating verbally, 75% of acousticians meet the architect less than 5 times/project (Fig. 5). This lack of personal communication highlights the potential lack of both parties' explanation of thoughts and design direction. Instead, a mediated method must be adopted though either

telecommunication or written reports. The distancing of both parties could be one of contributing factors for why acoustics is not implemented within architectural design. The implications of this issue could reach further than simply the New Zealand Building industry, with 70% of the Overseas participants indicating that they too attend 5 or less meeting throughout a project.

Acousticians tend to be introduced later into New Zealand building project than the same projects overseas. Every New Zealand building type, with the exception of apartments, is next to, if not, to the right of the corresponding overseas building (Fig. 1). This delay corresponds to an increase in remedial action required after design completion for each of the types except Auditoria and Office Buildings. This significant connection between a later introduction of an acoustician and an increase in remedial action suggests that the early intervention of acoustics limits the need for post-construction remedial work. This observation responds to a call for a shift in the industry “from developing acoustics from given spaces to developing spaces from given acoustics” [2]. As the changes suggested by an acoustician could occur at the early design stages, it is likely the cost of the remedial work would be significantly decreased for the client.

Despite having only a general understanding of acoustic principles, architects tend to focus on what has worked on previous projects, while challenging the project-specific recommendation made by the acoustician. All of 31 acousticians examined have, at some point in their career, been challenged by an architect. However, 71% of the acousticians believe that architects do not have the knowledge to understand why the specifications are in place. The issues raised in this investigation align to the colloquial evidence are expressed the two consultants.

## VI. FURTHER STUDY

A Master of Architecture (Prof.) Thesis has been proposed as a practical investigation with the grounding of these survey results. This research through design project aims to evaluate the prospect and potential limitations of parametric software through an underlying design process of cafe. Parametric design claims to be able to extract and optimise parameters to inform changes in the geometry [3]. Establishing these objective parameters is the initial phase of a four phase project:

### A. Understanding the Measures

To research the ability of parametric design to inform architectural design it is initially necessary to hypothesise what these parameters could be and how they could be objectively measured. This research proposal builds upon prior research completed by Legge et al.'s Otago University School of Medicine publication. Legge et al. measured a large sample size of 44 cafés in 2004 to explore whether noise levels in cafes determine the demographic of patrons who attend, and if any demographic group are socially excluded [4]. Legge et al. have been approached and agreed to share their raw data to form the basis for this project. More acoustically specific measurements will be completed on 12 cafes in the data acquisition phase.

### B. Data Acquisition Phase

Data will be extracted from 12 cafes to form effective cafes parameters. The 12 café were selected using a stratified sampling of the 44 cafes. Four cafes from each low, medium and high café volume bands will be elected for testing. This data will be captured through both qualitative and quantitative data: Objective Data will be measured with various types of acoustic measurements. Such measures could include background noise levels, unoccupied Reverberation Time (RT), Signal to Noise Ratio, Sound Transmitting Index (STI), Clarity (C50) and/or Definition (D50). Each measure analyses a different relationship between the user and environment. Another tool proposed to be utilised is IRIS. IRIS is a modern sound energy acquirement and analysis program that measures energy produced by a speaker in an empty room to produces a three dimensional visual representation of the architecture's influence on the acoustics [5]. To accompany these recordings, 60 patrons of the 12 cafés will be surveyed to gain subjective data that provide context to the objective data, informing conclusions of which acoustic room features are influencing the patrons' experience.

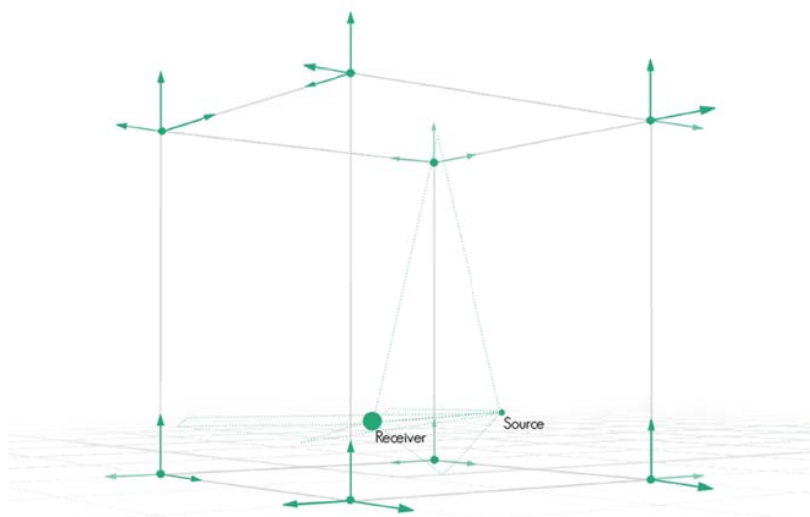


Fig. 6 Diagram illustration showing Galoppos' ability to alter each corner in three dimensions to produce a target acoustic reading

### C. Concept Phase

Pachyderm, a ray tracing plug in for Rhinoceros/Grasshopper, will be utilised to simulate acoustic readings within the room. Galapagos, an inbuilt tool in Grasshopper, and Octopus, a plug in tool, produces multiple design iterations by optimizing acoustic the parameters set in the data acquisition stage [6]. An algorithm has been written to allow Galapagos to alter the eight vertices of the box to find different forms that produce the targeted result established in the cafe testing section of this project (Fig. 6). Galapagos then alters the corners to create different design iterations (Fig. 7).

### D. Validation Phase

The findings of Pachyderm will then be validated against the original data recorded in the selected cafe. A digital model of this café will be created. The simulated results will then be compared to the physical readings. If the Pachyderm conveys similar information to the existing design, the importance of parametric design as a cost- and time-saving tool, in modern architectural design can be understood.

This design is an ongoing research project.

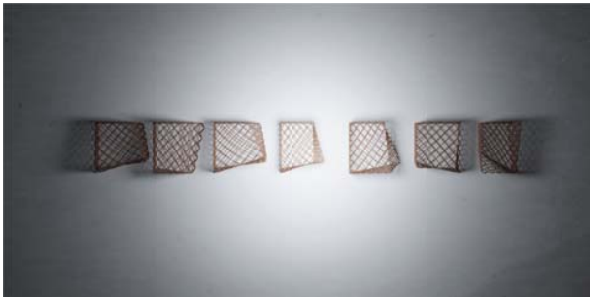


Fig. 7 Iterations of Results from Parametric process. All seven Iterations have a simulated clarity of 1

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