UNIVERSITY OF NAIROBI

FACULTY OF BUILT ENVIRONMENT & DESIGN

DEPARTMENT OF ART & DESIGN

INNOVATION OF ACOUSTIC INTERIOR DESIGN

TO IMPROVE AUDIO QUALITY

FOR HOME-BASED TELECOMMUTERS IN NAIROBI

BY

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Thesis submitted in partial fulfillment of the requirements for the Master
of Arts in Design, at the University of Nairobi.

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  iv. Co-supervisor

   v. Head of Master's Committee

  vi. Class Representatives

 vii. Research Participants

ABSTRACT

Introduction: *Working from home became more widespread in Nairobi during the year 2020. The COVID-19 pandemic was in full effect. Meanwhile, the Kenyan government had issued a shelter-in-place directive. Although restrictive measures have since been relaxed, a number of professionals based in the city continue to telecommute at least once a week.*

Problem: *Video calls are part and parcel of remote working, as they facilitate real-time communication between collaborators. When video calls and the home setting collide, a number of quality based issues arise. The ambient noises in the home environment adversely affect the audio quality of a video call. This has been identified as a cause of reduced worker productivity.*

Method: *Secondary research was carried out in the literature review chapter. The literature review successfully identified existing acoustic solutions. Primary research was carried out to pin point the pain-points of the target user. Analysis was then carried out to create a concept product for the urban Kenyan context.*

Proposed Solution: *The Design Thinking process was successfully used to ideate a concept acoustic product called ALTO.*

Conclusion: *ALTO is a lightweight acoustic panel made from recycled paper and made using items commonly available in the household. The panel is designed to be built by the telecommuter themselves. These three properties represent materials, labor and price innovation.*
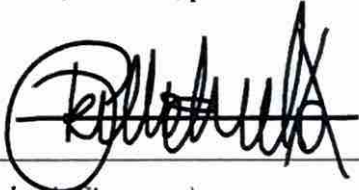
Keywords: *innovation, acoustic interior design, telecommuting*

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STATEMENT BY THE AUTHOR

This thesis has been submitted in partial fulfillment of requirements for the Master of Arts in Design degree at the University of Nairobi. This thesis is my original work and has not been presented for any other degree.

Brief quotations from this manuscript are permitted, provided that acknowledgement of the source is made. Requests for permission for extended quotation or reproduction of this manuscript, in whole or in part, may be granted by the University of Nairobi's Department of Design when the proposed use of the material is in the interest of scholarship. In all other instances, however, permission must be obtained from the author.

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(Author's Signature)   _____
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STATEMENT OF APPROVAL

As members of the Research Committee, we approve the submission of this thesis for examination. We recommend that this thesis be accepted as fulfilling the research requirements for the degree.

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Co-supervisor   *(Date)*

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CHAPTER 1.0: INTRODUCTION

1.1: KEY DEFINITIONS

The simplest definition of **innovation** is doing something in a new way. In the context of this thesis, innovation refers to the conscious act of improving on existing ideas (Stenberg, 2017). The urban Kenyan context is applied to existing solutions for Acoustic Interior Design interventions during video calls.

Acoustics is an engineering science that deals with sound transmission (Carley, n.d.). Interior Design is a profession that applies creative solutions to improve the quality of interior built environments. These functional and aesthetic interventions are subject to legal codes and building codes, which is why professional interior designers receive formal training before they can practice in the industry (Jamali, 2021).

Acoustic Interior Design is, therefore, the discipline of interior design that addresses the properties of a room to determine how sound is transmitted within the space. It represents a niche at the intersection between arts and engineering (Mahmoud, 2019).

Remote work defines any work performed by an employee from a different physical location than their direct supervisor. When the remote work involves use of telecommunication technology it becomes telecommuting.

Telecommuting can then further be outlined as the use of information and communication technology to partially or completely eliminate traveling to and from places of employment (Lamond et al, 1997). Working from home occurs when remote work or telecommuting are conducted from a person's place of primary residence.

A **video call**, also referred to as video conferencing, is the use of digital technology to facilitate real time meetings between two or more remote parties. Computing devices in conjunction with appropriate software are used to transmit image and audio virtually (Corliss, 2019).

1.2: BACKGROUND INFORMATION

1.2.1: Study Participants

The study includes three generations to represent the adult population in Nairobi City. The three demographic cohorts represent the majority age distribution of the adult population of Nairobi.

Source: Author

GENERATION X	GENERATION Y	GENERATION Z
LATCHKEY GENERATION	MILLENNIALS	CENTENNIALS/ZOOMERS
1965 - 1980	1981 - 1996	1997 - 2012
Tend to be overlooked as generations are being considered.	Came of age as internet use was becoming widespread.	On track to be the most educated generation yet.

Figure 1.2.1: Demographic Group Characteristics, 1965 to 2012
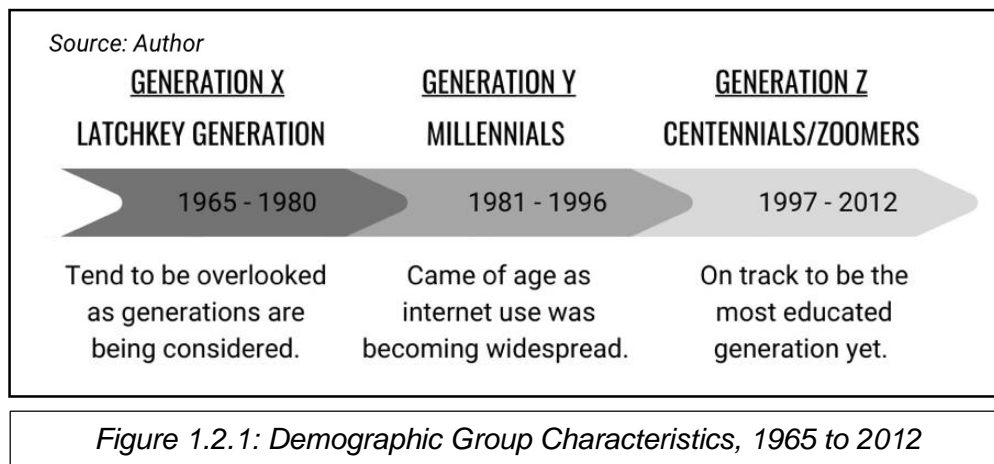
Millennials encompass persons in the demographic cohort born between the years 1981 and 1996. This generation accounted for the median of the labor force and market force globally in the year 2022, at which time they were aged between 26 and 41 years (US Chamber of Commerce, 2012). Also known as generation y, they are flanked on either side by generation z (centennials/zoomers) and generation x (latchkey generation).

1.2.2: The Rise of Telecommuting

The COVID 19 disease is a respiratory disease first reported in China in 2019. Its symptoms include fatigue, fever, coughing and breathing difficulties. The illness is airborne and can be transmitted through air droplets as well as contaminated surfaces (Africa CDC, 2022). As a result, the emergence of COVID 19 prompted a global shelter-in-place directive to be issued in early 2020, in an attempt to slow down its spread.

During this shutdown, travel was restricted and only essential services were allowed to operate. Urban areas experienced closure of schools, non-essential businesses and cultural venues. A significant portion of working professionals shifted to remote work models.

People who had previously never worked from home began telecommuting for five or more days a week (Sava, 2022). This led to a surge in video conferencing where video calls were used as a tool for digital meetings.
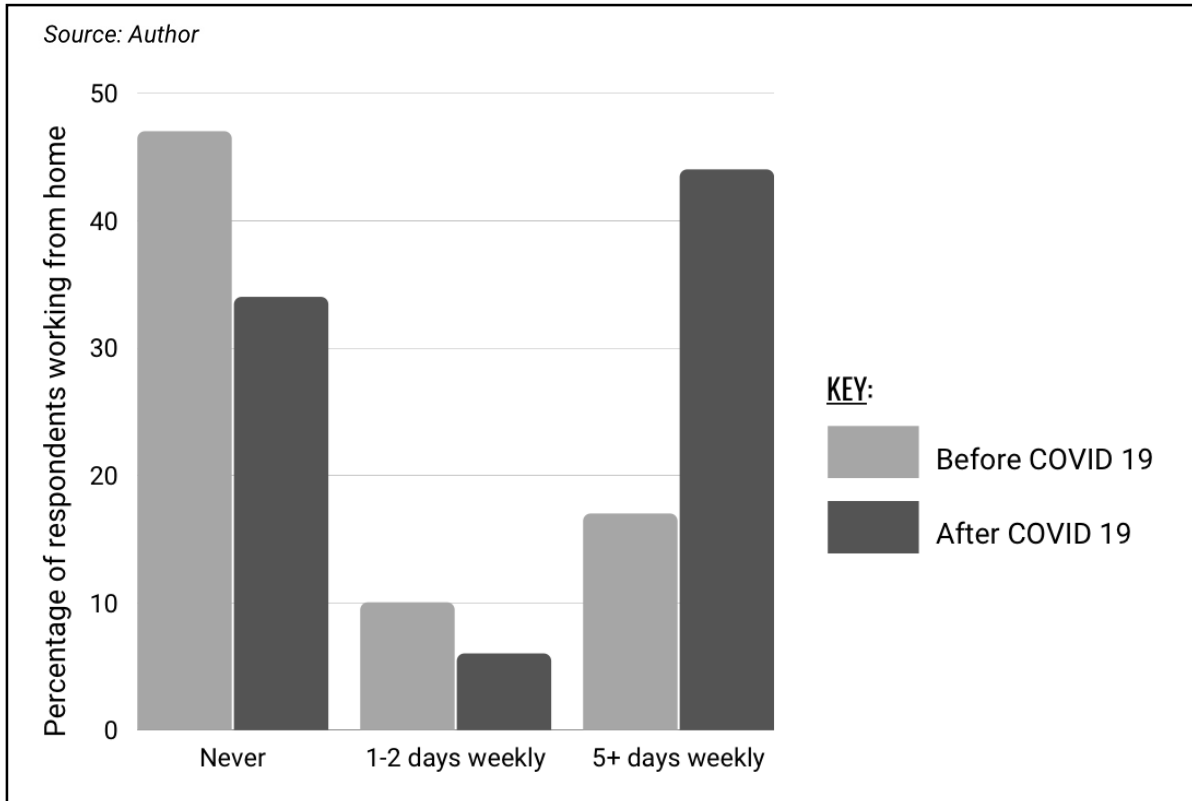
Figure 1 Remote Working Trends, 2019 & 2020

In 2022, the most commonly used video conferencing software applications for official video calls included Zoom, Google Meets, Skype, and Microsoft Teams. Official video calls encompass both virtual meeting rooms and virtual classrooms (Brandl, 2022).

Even as the COVID 19 pandemic slowly subsided (Tsiodras, 2022), working and learning from home became the future for most latchkey, millennial and generation z adults.
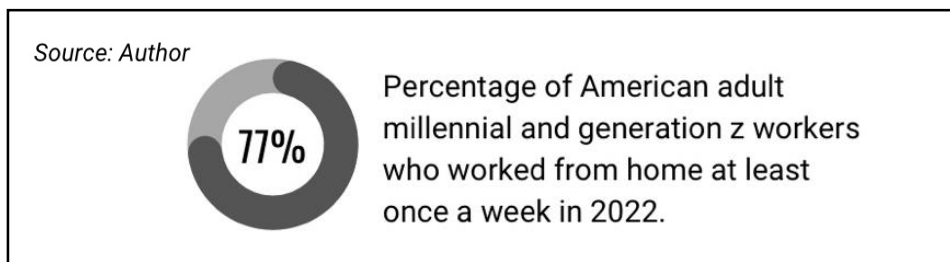
Figure 1.2.3: Remote Working Trends, 2022

According to a Pew Research conducted in 2022, 59% of employed American adults primarily work from their homes. Another 18% work from home at least once a week.

A part of working from home is participating in video calls. In the residential setting, video call quality can be hindered by ambient noise. Since telecommuting is on the rise (Eira, 2022), it may be worthwhile to explore new ways to improve video audio quality standards.

Other industries have already made contributions towards solving this problem. Device microphones are being improved year on year. Software programs that cancel out sound waves from disturbances already exist. But each of these interventions only improve video call audio quality by a certain percentage. When used in conjunction with each other, the results may prove astounding. Beyond the improvements yielded by tech upgrades and ICT solutions, acoustic challenges during video calls can be mitigated using interior design solutions.

Research Aim: To show how the Interior Design discipline can contribute towards innovation in solving the problem of reducing unwanted ambient noise during residential video calls.

1.3: PROBLEM STATEMENT

Home-based telecommuting has been on the rise in urban areas. The audio quality during home-based telecommuting is affected by ambient noises. In the residential setting, noise is mainly emitted by home inhabitants, domestic appliances and sounds from the surroundings of the home. Noise affects telecommuting productivity, particularly during video calls.

1.3.1: Outlining of the Issue

A growing number of latchkey, millennial and generation z adults are conducting their work and/or education from their home at least on a partial basis. Working from home includes participating in video calls using software such as Zoom, Google Meets, Microsoft Teams and Skype. The software selected depends on the consumer's use case. Zoom is most reliable for video calls with large numbers. Google Meets integrates seamlessly with other Google products. Microsoft Teams combines team chat and video conferencing well (Pot, 2022).
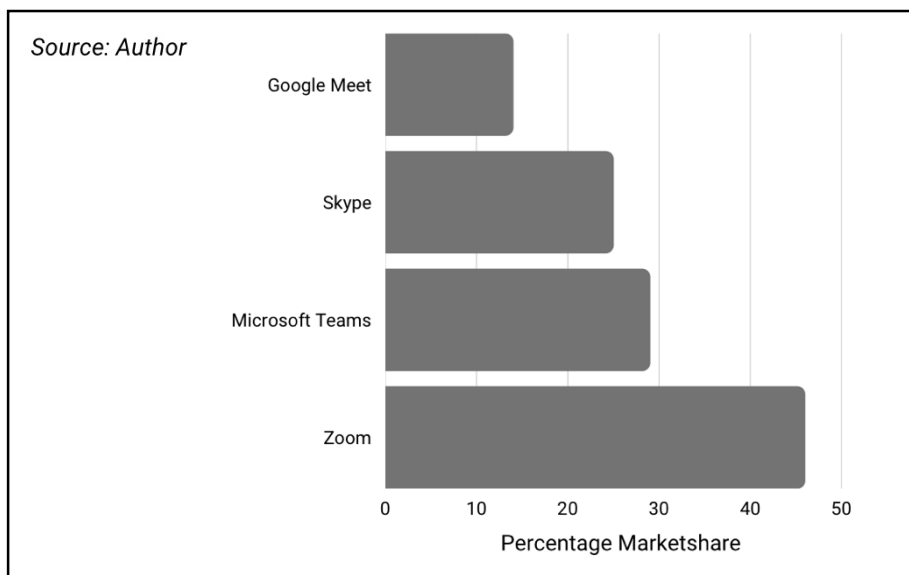
Figure 1.3.1: Video Call Software Marketshare, 2021

Video call participants can be classified as either passive or active. Active users include meeting hosts, presenters and facilitators. They usually have their microphone and/or camera switched on for interaction purposes. Passive users include audience members. Passive participants tend to be observers with both their microphone and camera switched off during the video call (Zhao, 2019).

Active video call participants in the residential setting face certain audio constraints. Audio interruptions during video calls in the home are mainly caused by:

- Sounds from other inhabitants of the home: this includes children and pets.
- Sounds from household appliances: some appliances' core function is to produce sound. Examples are TVs and radios. Other home appliances produce sound as a by-product of their operation. Examples are kettles, vacuums and washing machines.
- Sounds from outside: these sounds originate from around the dwelling as opposed to inside it. Sounds from traffic, aircraft and business vendors are good examples of this.

These sounds can overlap or occur individually (Wang et Norbäck, 2021). When they are present during a video call, they often interfere with the audio quality.

1.3.2: Context

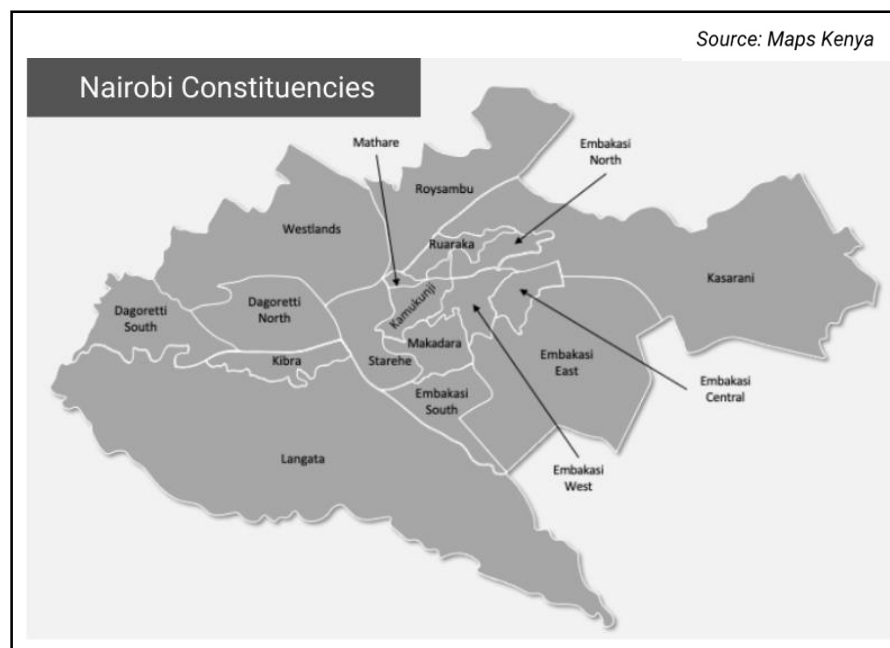The **geographical context** of this project is Nairobi City. Nairobi is the capital city of the Republic of Kenya with a population of approximately 4.4 million people as at 2019. The city is also a county with eleven sub-counties and seventeen constituencies gazetted in the year 2013 (CountryTrak Index, 2020).

Figure 1.3.2: Nairobi City Constituencies

The **demographic context** of this research is latchkeys, millennials and generation z (US Chamber of Commerce, 2012). Latchkeys represent the cohort of people born between the years 1965 and 1980. Millennials refer to the cohort of people born between the years 1981

and 1996. While generation z are the cohort of people born between the years 1997 and 2012, only the adult population will be included.

Roughly, these individuals would be aged between 18 and 60. This age group was selected because at the time, they represented the majority of the digital workforce in Nairobi.

1.3.3: Relevance of the Study

The unemployment rate in Kenya has risen slowly over the last ten years. In 2012, Kenya's unemployment rate was 2.83%. Almost a decade later, in 2021, it had climbed to 5.74%.
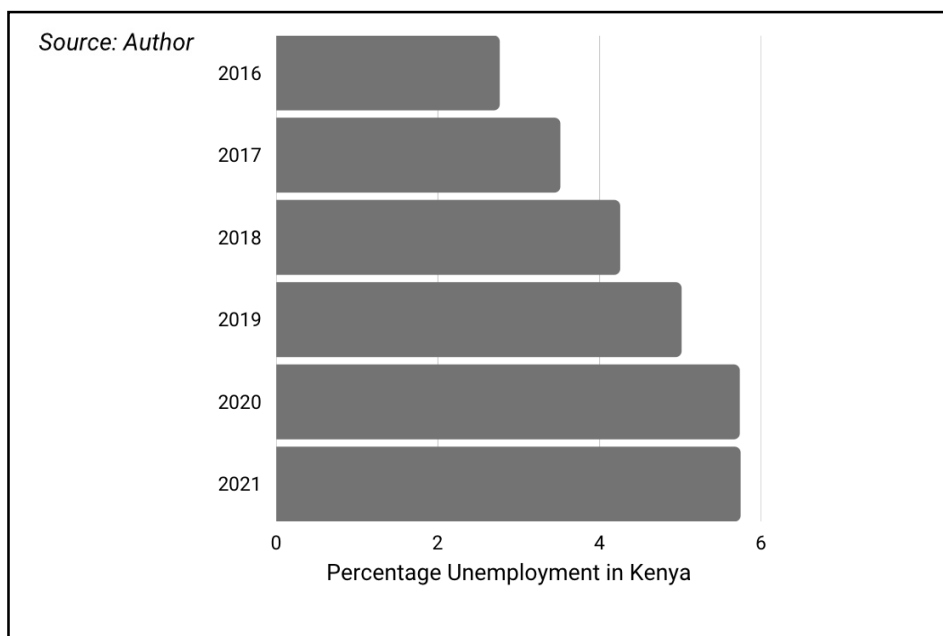
Figure 1.3.3: Unemployment Rates in Kenya, 2016-2021

As a large number of Nairobi millennials continue to face unemployment, they are turning to remote work to take advantage of global opportunities. This is both in the professional and education sectors. Most of this remote work is conducted online and from their places of primary residence.

The rise of home-based telecommuting creates an opportunity for innovation of Acoustic Interior Design.

1.4: SCOPE AND FOCUS

1.4.1: In Scope

The scope of this project is to formulate an Acoustic Interior Design solution that improves audio quality during domestic video calls. The scope is limited to residential telecommuters in Nairobi. This is inclusive of telecommuter office setups in a designated room as well as telecommuter office setups in shared/common spaces.

1.4.2: Assumptions

1. Telecommuting is home-based.
2. Ambient noise is present in said home.

1.4.3: Limitations

1. Gaining access to private residences for data collection.
2. Gaining access to requisite acoustic testing equipment.
3. Gaining access to participants for the entire duration of the project.

1.4.4: Out of Scope

1. Addressing non acoustic telecommuting concerns.
2. Addressing users outside of the urban context.

1.4.5: Hypothesis

Innovation can be achieved by studying existing acoustic solutions and establishing local user concerns. The innovation will apply the urban Kenyan context.

1.5: RESEARCH OBJECTIVE

The research exercise is being undertaken to innovate in the Acoustic Interior Design field so as to improve video call quality for home-based telecommuters in Nairobi.
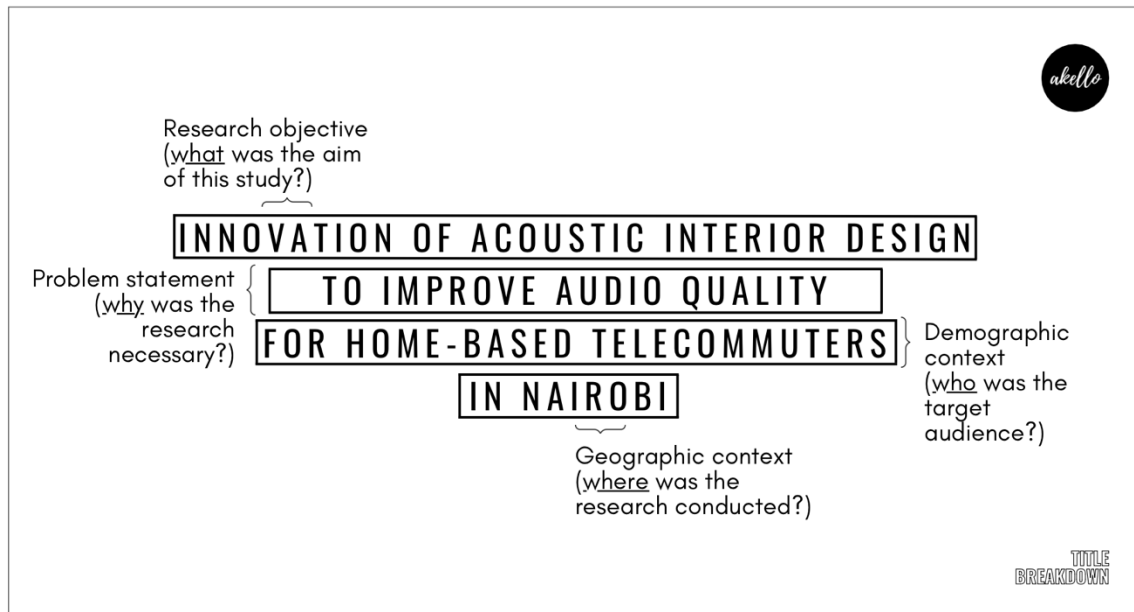
Figure 1.5.1: Thesis Title Breakdown

In order to innovate, information must be gathered on already existing solutions (Taylor, 2017). These solutions can then be adapted to the urban Kenyan context. The urban Kenyan user persona will be built by identifying user characteristics and user pain points.

1.5.1: Sub objectives

By breaking down the main objective, smaller research themes emerge to guide the study. These become the sub objectives and are as follows:

    i.   To establish the pain points of residential video call users in Nairobi.

    ii.   To identify existing interior design solutions for acoustics during video calls.

    iii.   To design an acoustic conceptual interior design product that improves domestic video call quality.

1.6: RESEARCH QUESTIONS

The research questions are drawn directly from the project sub-objectives. The research questions form the foundation for conducting the literature review. They will guide the topics to be studied and expanded on. They are:

    i.   What are the acoustic pain points of home-based video call users in Nairobi?

    ii.   What interior design solutions already exist for video call acoustics?

    iii.   How can existing solutions be innovated to apply the urban Kenyan context?
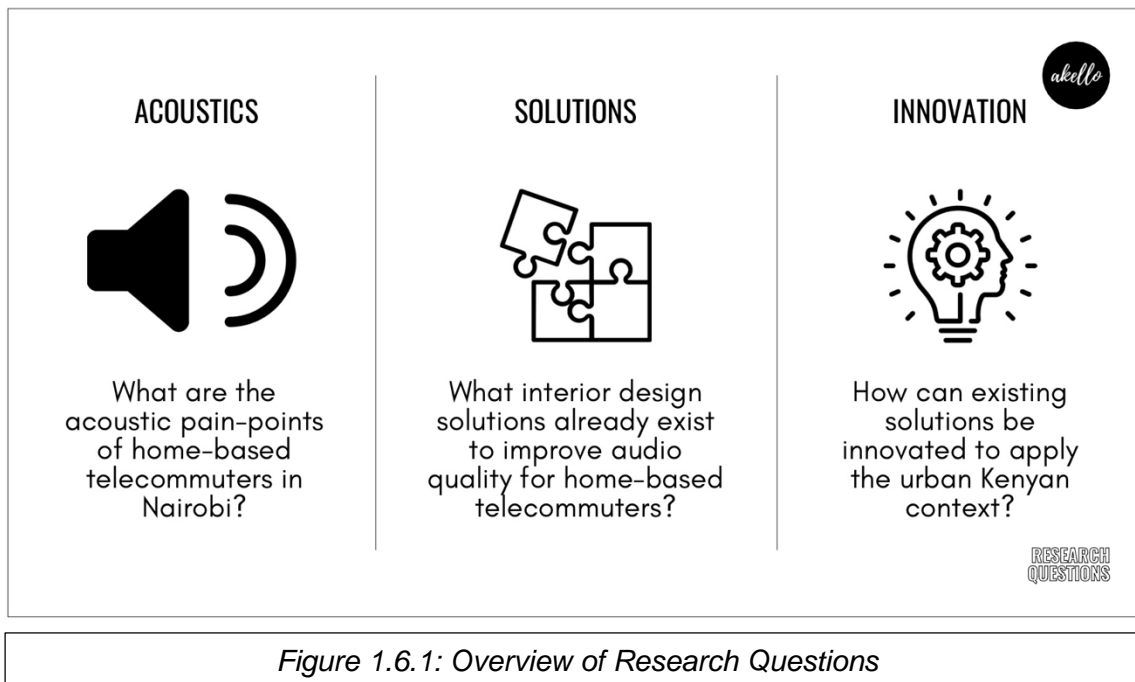
Figure 1.6.1: Overview of Research Questions

CHAPTER 2.0: LITERATURE REVIEW

2.1: INTRODUCTION

Acoustic Interior Design manages the sounds within a given interior space effectively. It aims to minimize unwanted sounds and to enhance wanted sounds. This facilitates the various human functions that are carried out within said space (Mahmoud, 2019). Although some solutions do exist to reduce ambient noise in the home, they are not adapted for the Kenyan market. This is where innovation comes in.

2.1.1: Understanding Innovation

Innovation refers to the act of improving on existing ideas. It is derived from the Latin word "innovare" which means "into new". Innovation is important for growth and development of the human race (Stenberg, 2017). Creativity and formulation of new ideas are crucial to the innovation process. Designing better versions of an idea or product can solve end-users problems in a way that previous generations did not (Taylor, 2017). The primary goal of this thesis is to innovate in the field of Acoustic Interior Design.

Figure 2.1.1: Types of Innovation

The following three types of innovation will be carried out:

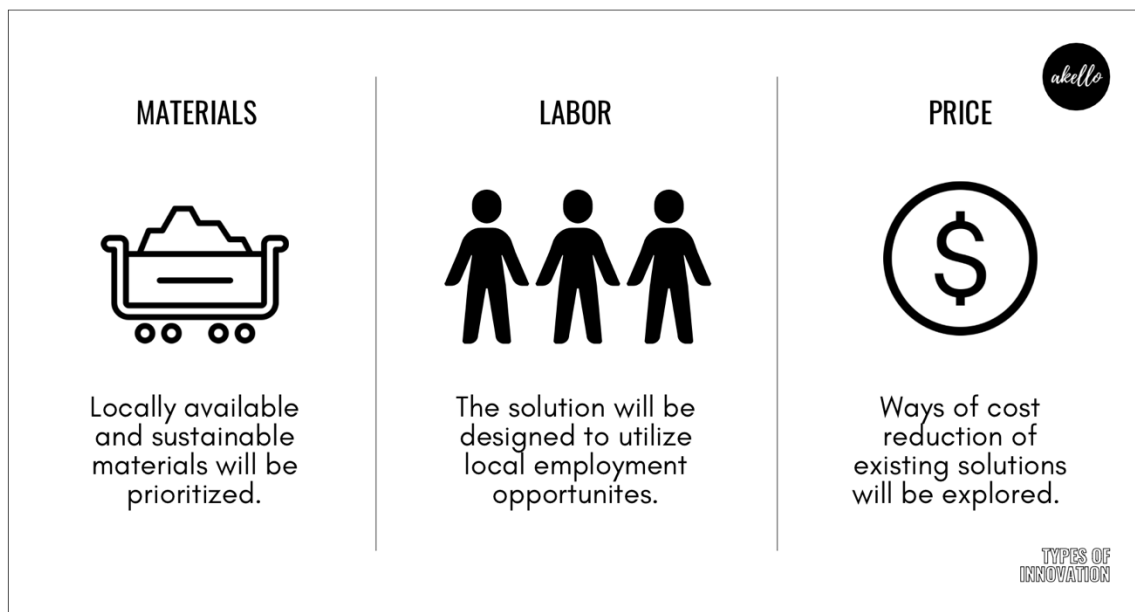i. **Materials Innovation:** raw materials form the basis of any product that is made. Concerns about the environmental impact of the raw materials being used in production can no longer be ignored (Onoyama et al, 2021). In addition, the COVID-19 pandemic has exposed global supply-chain flaws. Materials innovation may be the solution to finding sustainable and locally available materials to use in the solution of the issue raised in the problem statement of this thesis.

ii. **Labor Innovation:** Kenya is currently in the grip of an unemployment crisis. The economy simply isn't generating enough jobs to keep up with the number of laborers entering the market (Odinga, 2022). Kenya National Bureau of Statistics estimated that 36% of the country's workforce were unemployed in 2022, resulting in a growing dependency burden. Employment growth is anchored on economic progress. Continued innovation is necessary to enhance creation of employment opportunities on the African continent (Okumu et al, 2019). Labor innovation aims to create more employment opportunities.

iii. **Price Innovation:** most products globally are produced for the Western market, where wages are significantly higher than in developing economies (Pippo, 2018). The cost of purchasing these items is out of reach for third world markets. As a result, subpar items are dumped in these markets. Price innovation could facilitate the creation of a quality yet affordable acoustic interior design solution for the Kenyan market.

2.2: SOUND AND ACOUSTICS

2.2.1: Understanding Acoustics

Galileo Galilei is considered to be the father of modern day acoustic studies. Acoustics is a branch of physics that deals with how sound is produced, controlled, transmitted and received. It also covers the effects of sound (Mahmoud, 2019). Therefore, sound forms the foundation of acoustics.

From an engineering point of view, sound waves are defined as pressure variations that originate at a source and move through matter, causing regular oscillations between high pressure and low pressure (Berg, 2022). Not all sound waves are perceptible to the human ear.

Sounds that are unwanted and/or sounds that cause uneasiness to the ear are referred to as noise (Wawa and Mulaku, 2015). Noise is subjective and therefore the definition of noise can vary from person to person. However, there is a uniform interpretation for how the human ear interprets noise and it can be broken down into four standard types of noise as follows (Storey, 2020):

    i.   **Continuous noise:** produced over an extended period of time usually by some form of running equipment like a water pump.

    ii.   **Intermittent noise:** increases and decreases rapidly. An example is an airplane flying above your house.

    iii.   **Impulsive noise:** sudden bursts of sound that are startling in nature. An example is an explosion.

    iv.   **Low frequency noise:** the constantly present background sounds in the daily soundscape. It can also be described as chatter.

The types of noise, the sources of noise and the intensity of noise in the urban Kenyan residential setting are of interest for this study.

2.2.2: Properties of Sound

Before describing the properties of sound, it is important to define a few wave properties. A wave is simply an oscillatory disturbance that facilitates transmission of energy <u>WITHOUT</u> displacing matter (Singh, 2016).

Waves can be transverse or longitudinal, depending on how they are propagated (Berg, 2022). In a transverse wave, the vibrations occur in a direction perpendicular to the direction the wave is traveling. An example of a transverse wave is light waves. For longitudinal waves, the vibrations occur in the same direction as (parallel to) the direction the wave is traveling. Sound is a longitudinal wave.

The main properties of sound are as follows:

i. **Amplitude (A):** describes the magnitude of the displacement of molecules from the equilibrium point. Equilibrium is the undisturbed position of the molecule represented by the center line on the graph (Singh, 2016). Note that amplitude does not reflect the distance from wave crest to wave trough, but rather the distance from equilibrium to wave crest, or the distance from equilibrium to wave trough. The SI unit of amplitude is meters (m).

ii. **Period (T):** denotes the amount of time taken for a molecule to complete one full oscillation. A complete oscillation is called a cycle (Berg, 2022). A decrease in period results in an increase in pitch and vice versa. The SI unit of period is seconds (s).

iii. **Wavelength (λ):** it is the distance between two successive points in the sound wave i.e. from crest to crest or from trough to trough (Berg, 2022). Alternatively, the wavelength can be measured as the distance two successive equilibrium points of the sound wave. The SI unit of wavelength is meters (m).

iv. **Speed (v):** refers to the velocity with which a sound wave travels through matter. It is directly proportional to both the density of the matter as well as the ambient temperature (Talbot-Smith, 1993). Therefore, sound travels faster in denser matter as well as at higher temperatures. The speed of sound is slowest in gases and fastest in solids. Sound cannot travel in a vacuum, since there are no particles present to displace (Singh, 2020). The SI unit of speed is meters per second ($^m/_s$).

v.   **Frequency (f):** this is the number of wave oscillations per second (Berg, 2022). It is calculated as follows:

$$frequency = \frac{1}{T} \quad OR \quad frequency = \frac{v}{\lambda}$$

The SI unit of frequency is $\frac{1}{s}$ which is also called a Hertz (Hz).

vi.   **Intensity (I):** indicates the amount of energy carried in a sound wave. To the human ear, it translates as volume (Gillaspy, 2021). It is represented by the equation below:

$$I = 2\pi^2 f^2 A^2 \, \rho v$$

Where:

ρ = density of the medium in which the sound waves are traveling

The SI unit of sound intensity is Watts per square meter ($^W/_m{}^2$). However, the conventionally used units are derived from a human hearing threshold scale and expressed as decibels (dB).

Sound can be represented on a graph as a function of amplitude and time (Braginsky, 2020). The graph is a sinusoidal wave.
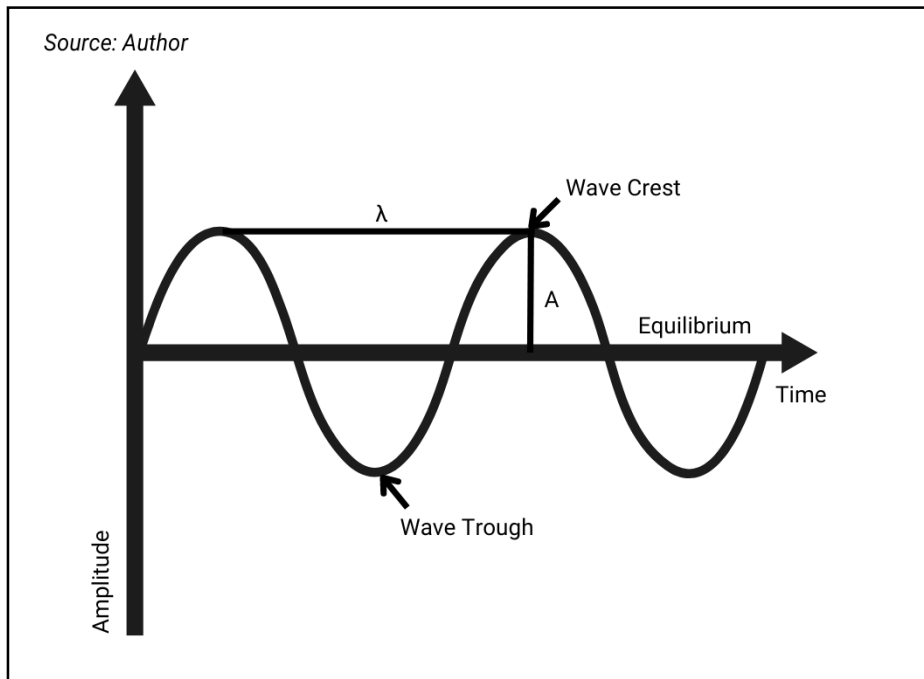

Figure 2.2.1: Graphical Representation of Sound

2.2.3: Distortion of Sound Waves

Distortion deforms the shape of a sound wave's output from a smooth curve to jagged, boxy or asymmetrical shapes (Vinnie, 2022). It is caused by the input being overdriven and usually manifests as clipping, intermodulation distortion and harmonic distortion (Dunn, 2015).
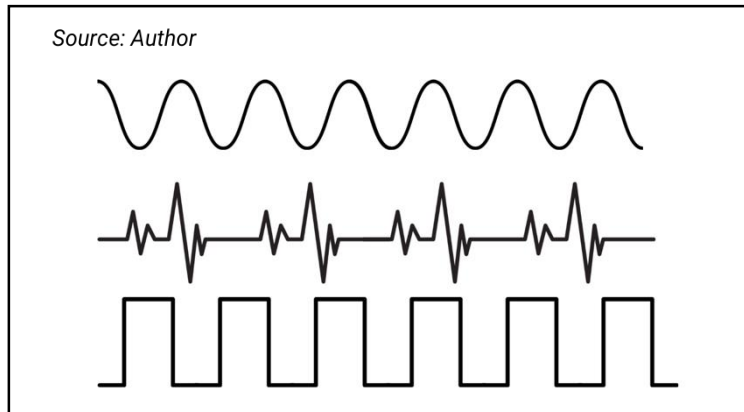

Source: Author

Figure 2.2.2: Sound Distortion

2.2.4: Interference of Sound Waves

When multiple sound waves are traveling together in the same medium, they interfere with each other Rather than bouncing off each other, they move through each other. The properties of the new wave that is formed depend on how the source waves align (Science Learning Hub, 2019).

Constructive interference occurs when sound waves of equal frequency and phase collide to form a wave of larger amplitude (Gillaspy, 2021). The higher the amplitude of the new wave, the louder the resulting sound. This is the mechanism through which microphones and amplifiers work.
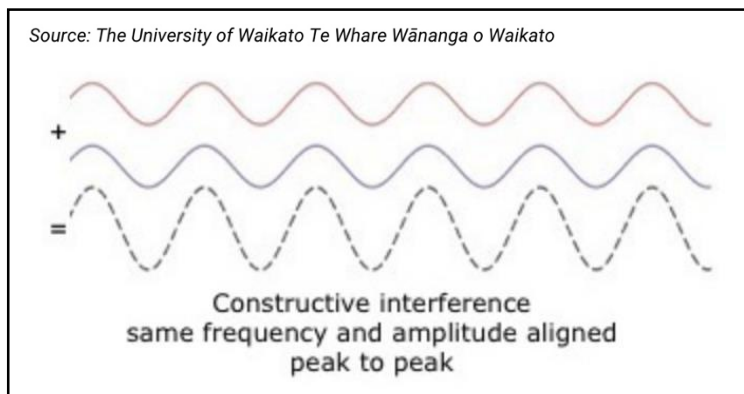

Source: The University of Waikato Te Whare Wānanga o Waikato

Constructive interference
same frequency and amplitude aligned
peak to peak

Figure 2.2.3: Constructive Interference

Destructive interference, on the other hand, occurs when sound waves of equal frequency but different phases collide (Gillaspy, 2021). The amplitude of the resulting sound wave is smaller than the amplitude of any of the original waves. If the phases line up at the midpoint of the wavelengths, the new wave will have an amplitude of zero and no sound will be heard. This is the mechanism through which noise cancelling headphones work.
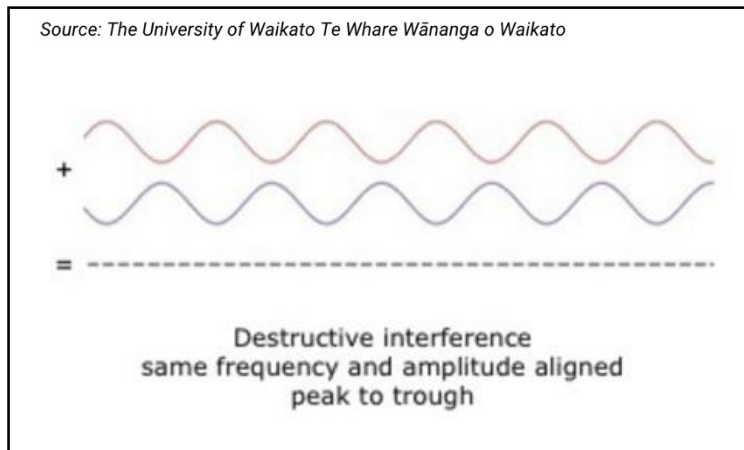

Figure 2.2.4: Destructive Interference

2.2.5: Reflection and Absorption of Sound Waves

When it comes to acoustic interior design, sound waves are treated by the mechanisms of reflection and absorption (Mahmoud, 2019). The mechanism of sound alteration is determined by the nature of the surface material being used. While reflection of sound waves increases sound intensity, absorption of sound waves reduces sound intensity.
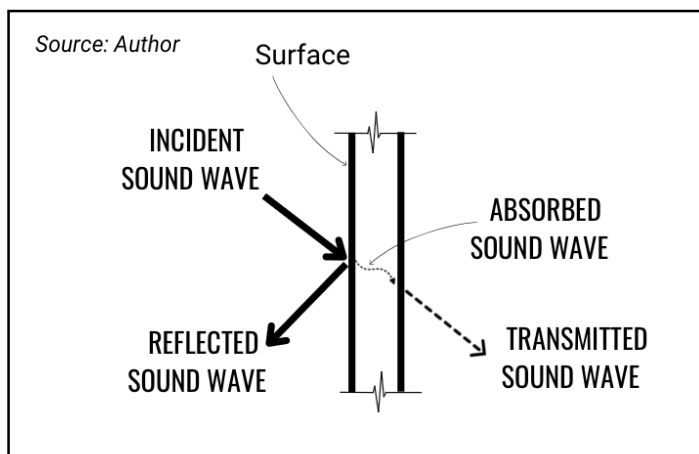

Figure 2.2.5: Reflection and Absorption of Sound

When sound waves strike a hard enough surface, they are reflected. During this process, some of the energy of the sound wave is dissipated. The ability of a surface to reflect a sound

wave is dependent on the reflection coefficient (R) of said surface. During sound reflection, the angle of reflection is always equal to the angle of incidence. The incident sound wave, the reflected sound wave and the normal all fall on the same plane.

Sound reflection results in diffusion, reverberation or echoes depending on the shape of the surface that the sound wave hits. A concave surface focuses sound making it louder, a convex surface scatters sound and an irregular surface diffuses sound (Mahmoud, 2019).

Sound absorption refers to the reduction of sound intensity when sound waves encounter and absorbent surface. This reduction is as a result of loss of energy from the incident wave. Acoustic treatments that utilize absorption are commonly used to reduce echoes and reverberation in theaters (McIver, 2023). This improves the intelligibility of the performers on stage.

Note: Echoes and reverberation may serve to make indoor spaces even louder than expected. This happens because sound waves persist even after sound from the source has been terminated (Roberts, 2018). The result is the presence of additional background sounds.

2.2.6: Sound in the Residential Setting

Sound can be measured using pitch and intensity. The pitch of sound is determined by the frequency of the sound waves. Higher notes have higher frequencies and lower notes have lower frequencies. The human ear can perceive frequencies ranging from 20Hz to 20,000Hz (Singh, 2016). This perception range diminishes as a person ages.
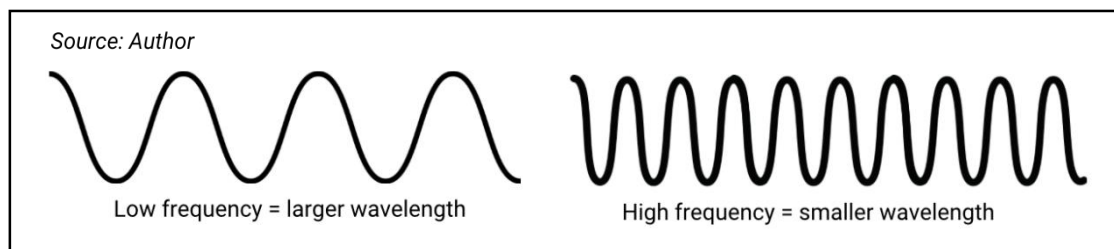

Figure 2.2.6: Pitch Graphical Representation

Intensity is the volume of the sound. The higher the intensity, the louder the sound and the lower the intensity, the quieter the sound. Intensity is related to the strength of the sound vibrations (Gillaspy, 2021). Sound intensity is measured using decibels (dB). The noise level

in offices is between 50 - 60dB. In most countries, noise levels of 85dB are considered to be the maximum acceptable safe volumes for 8 hours of exposure a day (International Labor Organization, n.d.).

Most household noises that negatively affect video call audio are intermittent. In the context of this thesis, noise present in the home comes from three main sources:

- **Household Inhabitants:** the living beings that occupy an indoor space can be a source of noise pollution during video calls. They include children, adults and pets.
- **Household Appliances:** the use of home appliances has been on the rise. Machines that operate noisily (for instance vacuums, washing machines and kettles) are being used to ease domestic tasks (Fatima and Mohanty, 2012). Other appliances such as TVs and radios are designed to emit sounds as part of their functionality. All of these acoustic interferences affect the audio quality of a video call in the residential setting.
- **Street Noises:** noises that emanate from outside the home include vehicular traffic, business activities and children playing. A 2015 study by Wawa and Mulaku revealed that the street noise levels in Nairobi CBD varied from 61 decibels to 78 decibels. While these noise levels may be lower in residential neighborhoods, the study gives a good indication of the sound profile of the city.

2.3: EXISTING ACOUSTIC INTERIOR DESIGN TREATMENTS

2.3.1: Acoustic Reflectors

Acoustic reflectors are rigid, non-porous materials with hard surfaces that reflect sound waves. Their application is in increasing the intensity of sound while maintaining quality. Uniform dispersion of sound waves in varying direction can be achieved by using an irregular reflection surface. Islamic civilizations have been known to utilize this phenomenon to amplify the religious call to prayer (Mahmoud, 2019). An example can be seen at the main mosque in the Gedi Ruins of Malindi, Kenya.

Although the amplification property of sound reflectors is counterintuitive to the project goal, investigating them still provides useful insights. Acoustic reflectors tend to be made from hard natural materials which are quite costly. This presents an opportunity for price innovation.

2.3.2: Acoustic Foam

Acoustic foam is an insulation material made up of open cells that absorb sound waves. The energy of the sound waves moves around the cells, creates friction and gets converted to heat energy (Foley, 2020). This process diminishes the amplitude of sound waves. Acoustic foam captures middle and high frequency sound waves which have shorter wavelengths than the low frequency ones. It is most effective in eliminating echoes and reverberations (Bone, 2013). For a video call, the result is noise reduction as well as a better quality of remaining sounds.

Acoustic foams are lightweight and versatile. They come in many shapes, colors and sizes. They can be installed on both walls and ceilings for maximum efficiency. Most acoustic foams are made from petrochemicals. They are also infused with dyes, fire retardants and other harmful chemicals. This presents an opportunity for materials innovation.

2.3.3: Acoustic Seals

Sound insulation works to prevent sound waves from traveling between separate rooms/partitions. Acoustic seals are used to fill any gaps through which sound waves may enter or escape an interior space (Acoustic Geometry, 2022). In order for Acoustic seals to be effective, the room must be closed off. They are only applicable for home offices in a dedicated room where one can close the doors and other fenestrations.

Acoustic seals need to be installed in a precise manner in order for them to be effective. They must be applied to any possible entry points for sound into a room. This means that specialized skills are required installation. This presents an opportunity for labor innovation.

2.4: SUMMARY

Innovation involves first identifying existing solutions. There are already acoustic interior design products available on the global market. These products can be broadly categorized into three types based on their mode of functioning.
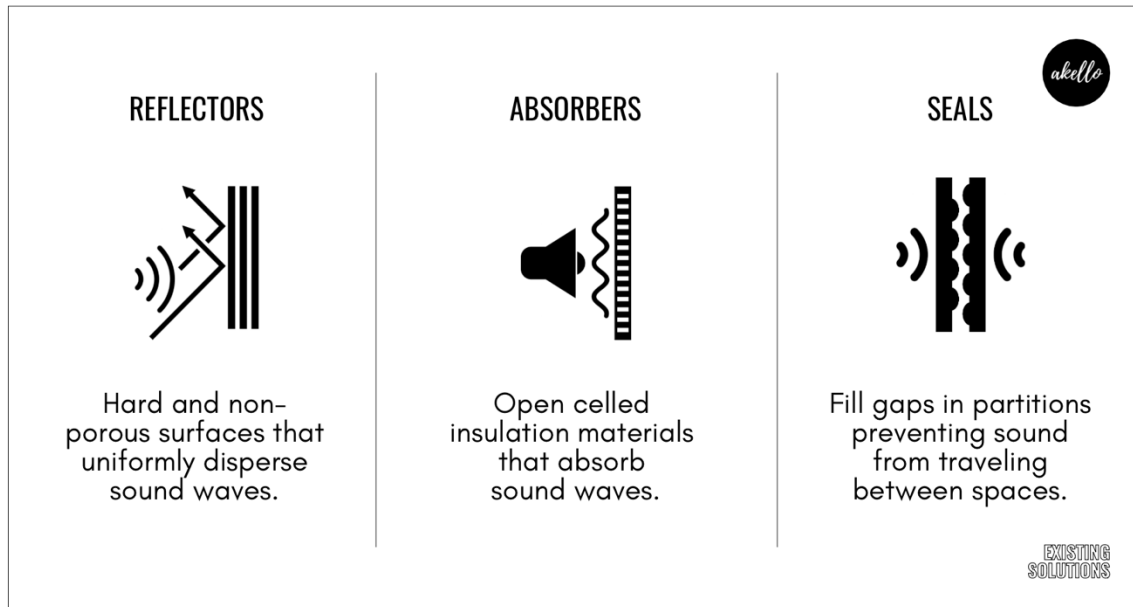

Figure 2.4.1: Existing Acoustic Interior Design Solutions

Secondary data was collected by conducting a literature review. This literature review explored the inner workings of sound waves. It also identified the already existing solutions for video call acoustics. This addresses the second research question.
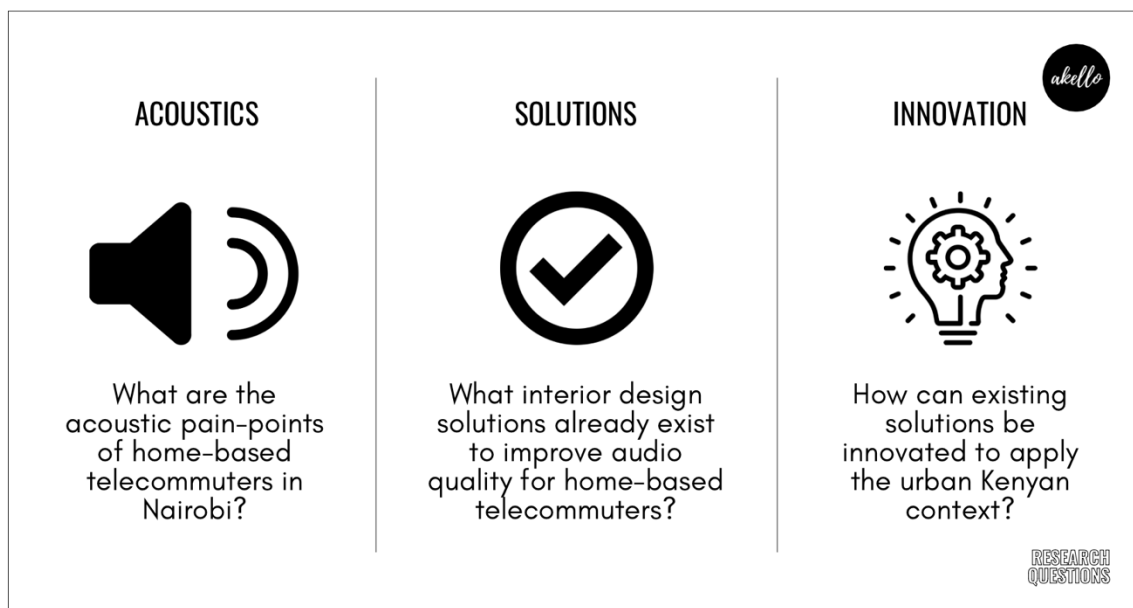

Figure 2.4.2: Research Questions Checklist I

2.5: CONCEPTUAL FRAMEWORK

A visual representation of the concept development gives an organized picture of the Design Thinking process being employed. The process is circular, not linear, but will ultimately begin with an attempt to understand the problem. It will provide guidance throughout the duration of the project.

The innermost ring represents the Design Thinking steps: understand, define, ideate, design, prototype and validate. The middle ring defines the methodologies used to execute the aforementioned steps. The outermost ring outlines the expected output for each Design Thinking step.
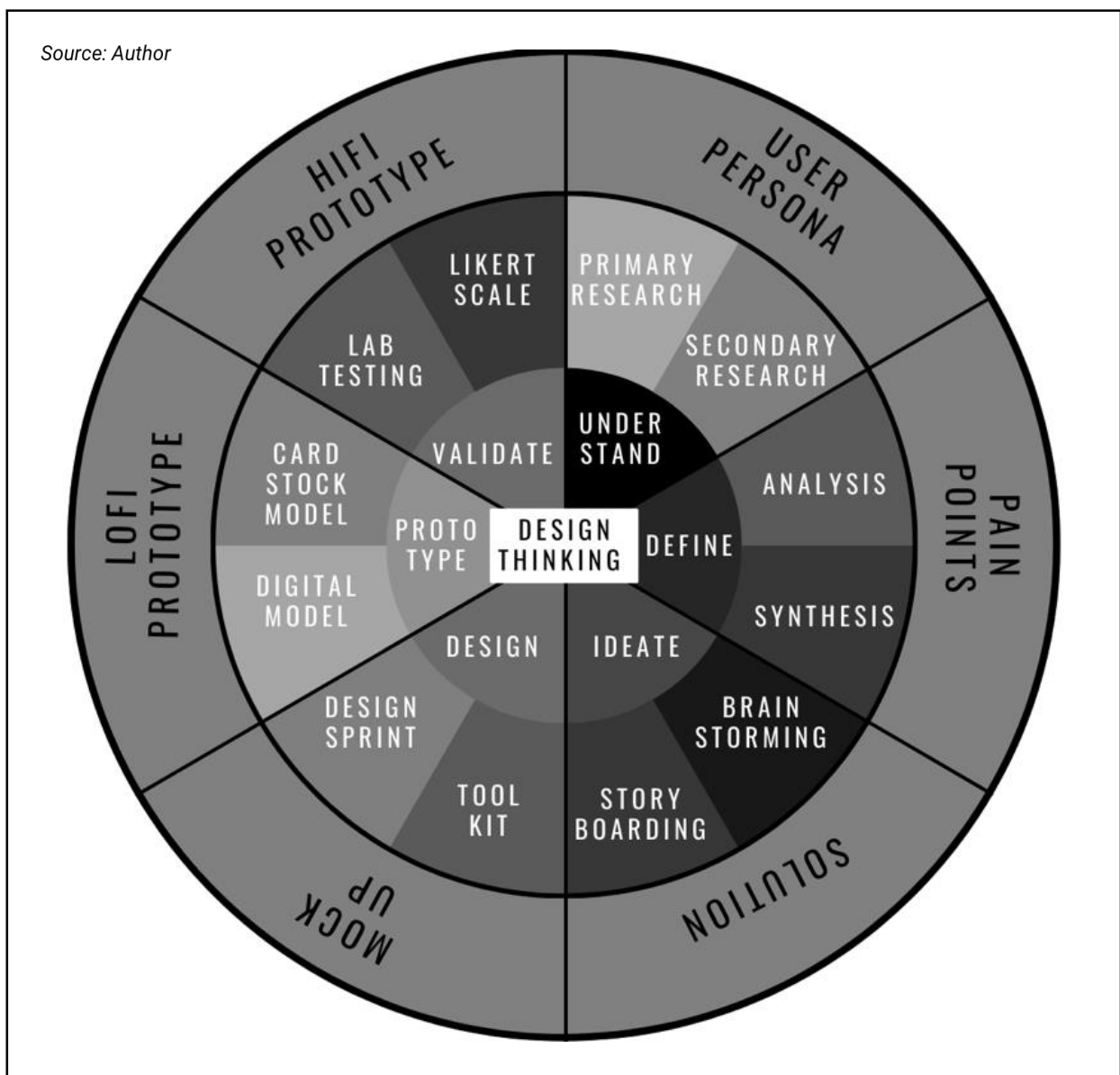

Figure 2.5.1: Conceptual Framework

The conceptual framework can be broken down slice by slice, depending on where in the Design Thinking process the researcher is. Secondary research has been carried out in this chapter. In the upcoming chapter, primary research methods will be covered.
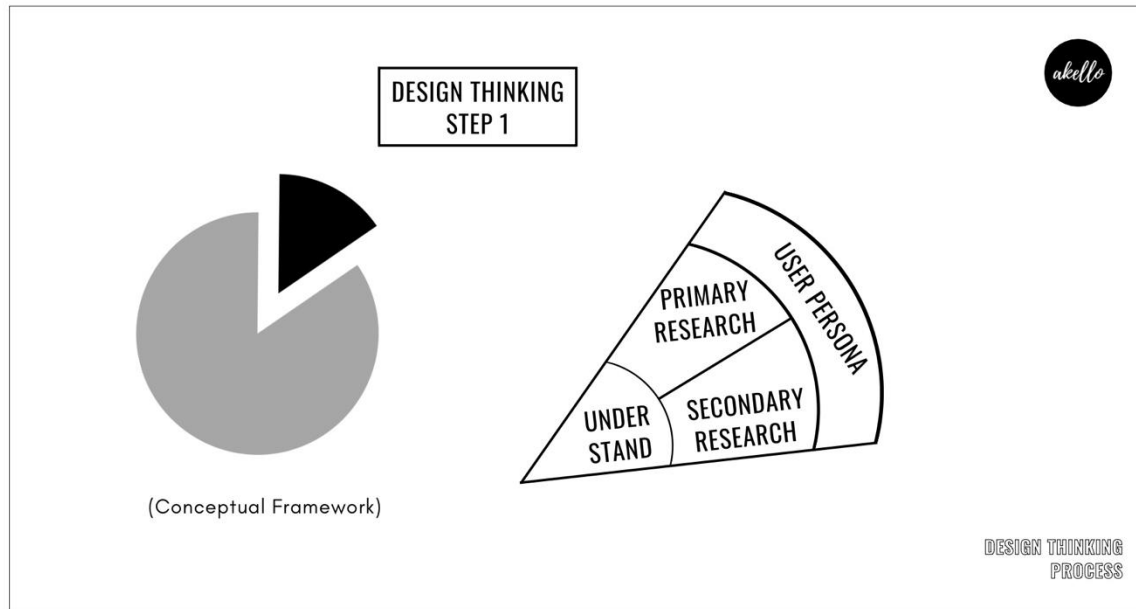

Figure 2.5.2: Design Thinking Process I

CHAPTER 3.0: PRIMARY RESEARCH METHODOLOGY

3.1: INTRODUCTION

Home-based telecommuting has been on the rise in urban areas. The audio quality during home-based telecommuting is affected by ambient noises in the residential setting. In order to solve this problem, the researcher undertook to innovate in Acoustic Interior Design.
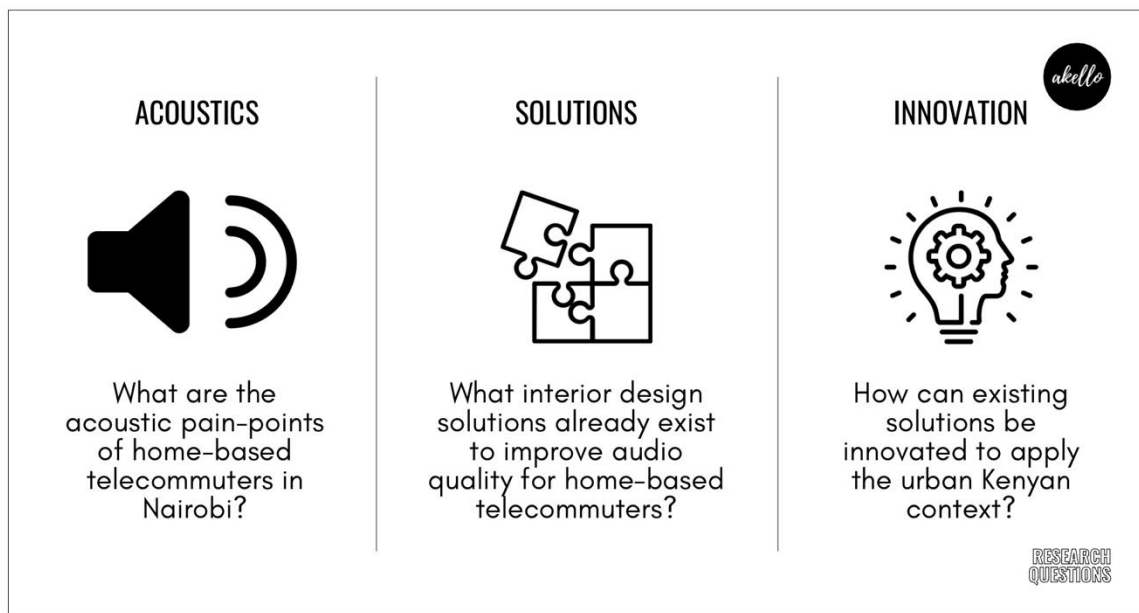
The research questions are summarized as follows:

Figure 3.1.1: Overview of Research Questions

The upcoming research methodology outlines the steps taken to conduct the primary research that answers Question 1. Question 2 has been answered by conducting secondary research in the literature review chapter. Question 3 will be answered in the analysis section.

3.2: RESEARCH DESIGN

The research design outlines the strategy that the researcher employed to conduct their study. It entailed selecting tools and techniques for data collection, data analysis and problem solving (Romanchuk, 2023). A research design that could accommodate the Design Thinking process was prioritized.

3.2.1: Logic of Enquiry

Research methodologies can be broadly categorized as quantitative methods and qualitative methods. They are distinguishable by the type of data they collect. Quantitative methodologies collect numerical data and qualitative methodologies collect non-numerical data (Maina, 2012). The logic of enquiry selected was determined by the desired outcomes of the study.
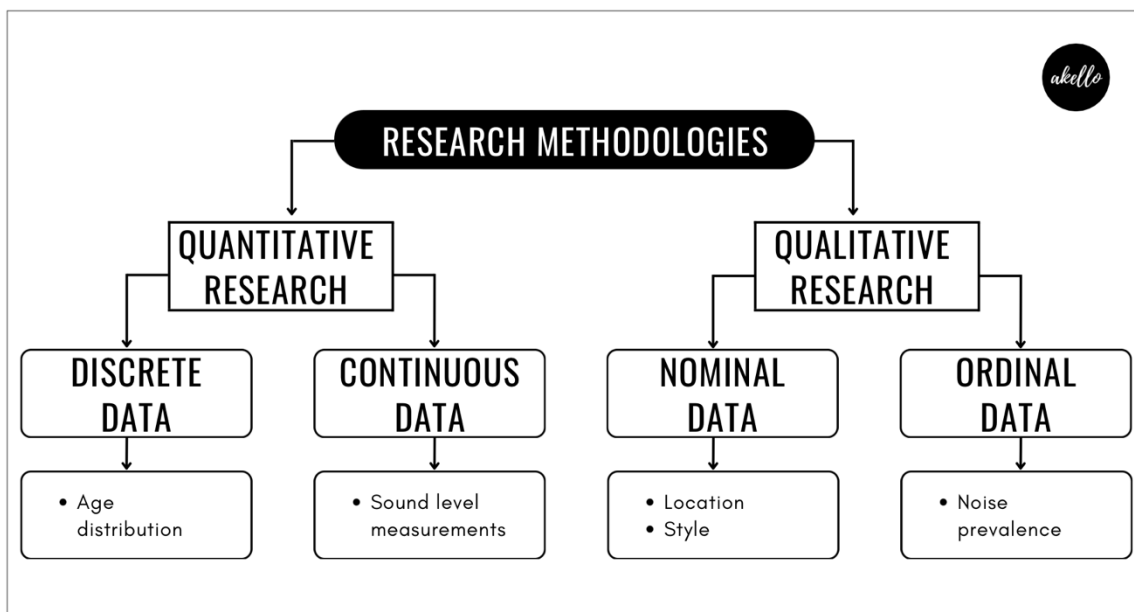
Figure 3.2.1: Research Methodologies

When using quantitative research methods, the temptation is to make concrete and defined conclusions. This takes out the human element from any decisions made using quantitative data (Cornell, 2022). Design Thinking, which is a part of the solution process, is strongly attached to the idea of consideration of the end user. Behavioral characteristics, emotions and nuances cannot be captured effectively by using purely quantitative methods.

The two types of quantitative data are discrete data and continuous data. Discrete data displays information for a particular event, while continuous data shows trends over time (Indeed Editorial Team, 2022). Also, discrete data is represented as only whole numbers that cannot be meaningfully subdivided, while continuous data may include fractions and decimals that could therefore have an infinite number of possible values (Todd, 2021).

Qualitative methods are quite favorable in bridging the data gap of the human element. They take into consideration things that cannot be quantified (Adedoyin, 2020). However, a purely qualitative approach may result in products that are functional in theory, but not feasible to produce. A touch of sound numerical logic promotes success.

The logic of enquiry for this project was, therefore, a combination of quantitative and qualitative research methods. This hybrid research design accommodated the Design Thinking process as well as presented non refutable data sets for consideration.

Source: Author

QUANTITATIVE RESEARCH   Hybrid research model   QUALITATIVE RESEARCH

Figure 3.2.2: Logic of Enquiry
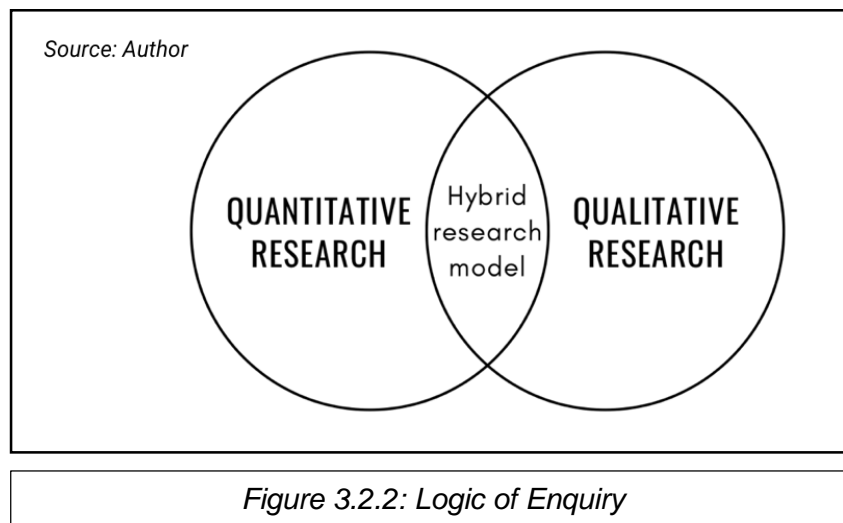
3.2.2: Research Philosophy
The research philosophy reflects the researcher's beliefs about the manner in which data should be gathered and analyzed. A pragmatist research philosophy was adopted for this study. Pragmatism rejects the idea that one reality can give full insights. It therefore combines mutually compatible philosophies.

The nature of data being sought was both qualitative and quantitative. Positivism was adopted for quantitative data while interpretivism was adopted for qualitative data.

Positivism is rooted in the belief that valid information is gained through observing and quantifying (Dudovsky, 2023). The role of the researcher should be data collection and data interpretation without interfering or interacting with the study environment (Cropley, 2022). The goal of the researcher is to reduce phenomena to their simplest elements.

This operationalizing of concepts makes it easier to focus on facts. In the case of this study, the sources of ambient noise during home-based telecommuting were narrowed down in the secondary research. The prevalence of each noise source was then observed in the primary research. Sound levels are also measured and recorded. Both of these data sets are epistemological. Epistemology involves the use of scientific methods to collect measurable facts. It is one of the research methods associated with the positivism research philosophy (Dudovsky, 2023).

Interpretivism is rooted in the belief that reality can only be understood through the subjective intervention of the researcher (Dudovsky, 2023). While this leaves room for many interpretations of collected data, interpretations are subject to the expertise of the researcher. In this study, the researcher has received engineering training and has seven years of experience in the Interior Design field. All data interpretations of qualitative data were influenced by the researcher's background.

Research findings in positivism studies are only descriptive. An interpretivist philosophy was applied to qualitative data research. The depth of insights facilitated creation of a user persona for the Design Thinking process being used to create a solution to the problem statement.

3.2.3: Research Type

Descriptive research involves studying a population and outlining their characteristics (Manjunatha, 2019). A descriptive research type was selected to discover the acoustic pain-points of home-based telecommuters in Nairobi.

The research questions for this study were summarized in a diagram to allow easy reference. Descriptive research works best when research questions are clearly defined and can be used for both qualitative and quantitative research.

3.2.4: Research Strategy

Design Thinking was selected as a research strategy because it is an approach that aims to examine the end consumer's perspective with the goal of uncovering their unmet needs (Turnali, 2015). Design Thinking has its origins in the 1960s when attempts were being made to make design more scientific. However, the principles were not well defined until about a ten years later (Dam and Siang, 2022). The development of Design Thinking as a practice continued over the next few decades. David Kelley went on to found Stanford University's D.School in 2004. The school works towards the development of Design Thinking practice globally.

Design Thinking is a non-linear process that involves understanding the user, defining the problem, ideating a possible solution, designing a prototype, and finally, testing the output for its efficacy in solving the outlined problem (d.school, 2010). The process is then repeated as needed making Design Thinking a cyclical rather than a linear approach. This is why the conceptual framework is represented as a circle.

The primary aim of this thesis is to innovate in the acoustic interior design field. This means identifying existing alternatives and then adapting them to the urban Kenyan context. The Design Thinking approach is suitable for improving existing products to better suit the target consumer's needs. By utilizing Design Thinking as a strategy, this researcher hopes to anticipate the current and future needs of the target group. This will allow ideation of a solution that is not just effective, but also serves the user for the long-term.

The circular process is useful when it comes to innovation attempts, because it allows several iterations of a process. Using a Design Thinking strategy means that other researchers should be able to pick up where this author leaves of.

3.3: DATA COLLECTION TOOLS

Data collection is the process of gathering and measuring information during research. The data collection tools were tailored to the type of data being sought. **Fieldwork** was used to identify sound levels in private Nairobi residences. The fieldwork yielded continuous quantitative data and nominal qualitative data. A **survey** was used to establish demographics of the participants and identify their telecommuting habits. The survey yielded discreet quantitative data, nominal qualitative data and ordinal qualitative data.

3.3.1: Sampling

Sampling represents the technique of selecting the population that the research will be conducted on (Cornell, 2022). The population of the study denotes the entire group that the researcher wants to study. The sample indicates the specific individuals from that group that data will be collected from (Maina, 2012).

In the case of this project, the target population is home-based telecommuters in Nairobi. This population was selected based on geographic, demographic and behavioral characteristics that were of interest to the researcher.

When using sampling as a method for conducting quantitative research, the two options available are probability sampling and non probability sampling (Adedoyin, 2020).
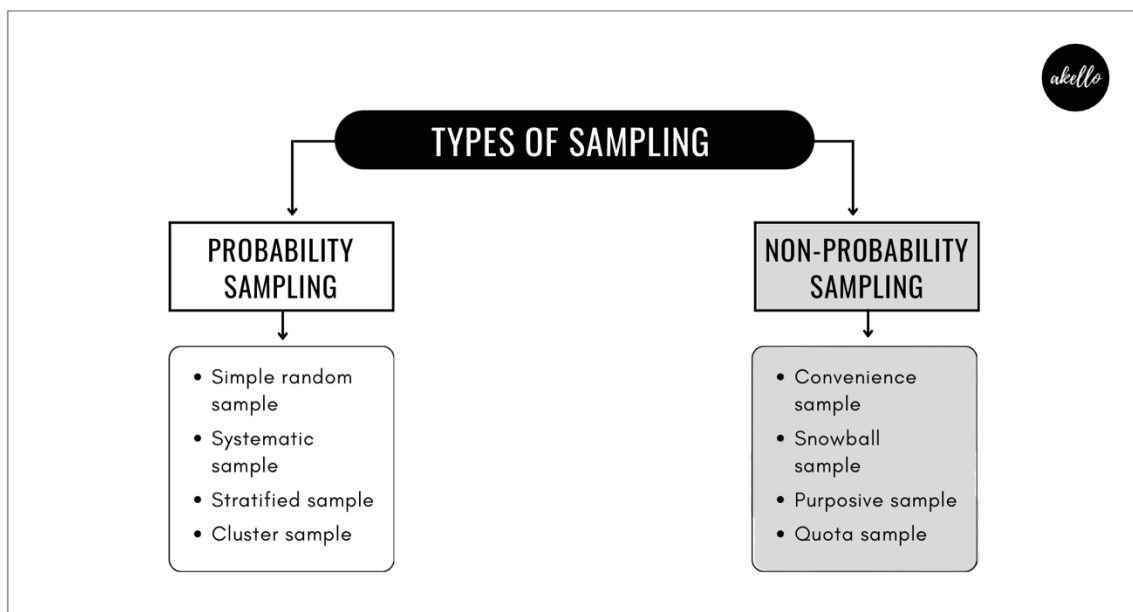

Figure 3.3.1: Sampling

Probability sampling relies on randomly selecting participants from the target population. Some examples of probability sampling are cluster sampling, systematic sampling and random sampling. Every member of the target population has an equal likelihood of being selected as a sample.

Non probability sampling facilitates the researcher to pick samples from the target population as per their own judgment. Non probability sampling methods include consecutive sampling, snow ball sampling, convenience sampling and quota sampling.

Convenience non-probability sampling was used to select the fieldwork participants. Persons in each sub-county were selected based on their familiarity to the researcher. Participants were technologically literate, and had prior experience with home-based telecommuting.

This choice is based on limitations with obtaining access to a participant's residential home for an extended period of time, which was a pre-requisite for the two-day fieldwork. Unless some form of monetary compensation is afforded, most participants are unwilling to comply. This compensation was not available in the project budget. Although probability sampling methods such as random sampling would have yielded better quality data, the project budget could not accommodate this either.

Snowball non-probability sampling was used to select survey participants. The researcher began with a small group of home-based telecommuters in Nairobi. The selected initial participants then shared the digital survey with other contacts who fitted the population criteria.

3.3.2: Fieldwork Design

Prior to the field test, the researcher conducted a pre-test to determine the loudest part of the day. Sound readings were taken every morning and afternoon for two weeks. These readings were taken in the researcher's own residence. Analysis of the pre-test findings indicated that afternoons were louder than mornings. So these were the times selected for the fieldwork activity. Although the values may not be representative of sound conditions in other areas of Nairobi, it was useful to establish certain baselines to confine the study.

A fieldwork exercise was then set up to collect sound level readings in private residences from each of Nairobi's sub-counties. Each iteration of fieldwork exercise lasted for two days and was conducted on the weekends of April 2023.

A mobile phone was the primary data collection tool during the fieldwork. Sound collection software was used to turn the phone into a detection device for ambient sound levels in the participating households. Different versions were used as per the participant's operating system. Both apps allowed the phone to function as a sound collection device and were available for free download in the Google Appstore .
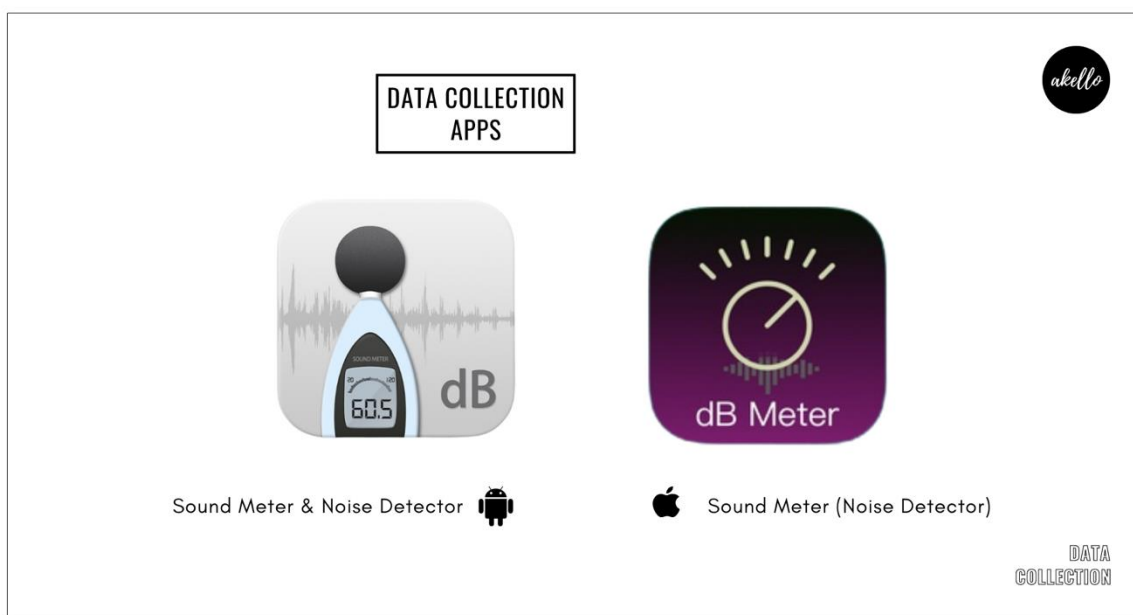
Figure 3.3.2: Fieldwork Data Collection Apps

Participants were technologically literate, and had prior experience with home-based telecommuting. They were selected based on familiarity to the researcher. A total of seven participants carried out the field work. This number is inclusive of the researcher, who collected readings from three sub-counties.

Each participant was instructed to carry out a practice run to ensure a smooth running on the actual test days. This activity involved opening the Sound Meter app, allowing it to run for a minimum of 42 seconds, and then pressing the "STOP" button. Of the three values that appeared on the screen, the maximum sound reading was recorded in decibels (dB).

The test was ran in the same manner. Sound level data was recorded on a consecutive Friday and Saturday afternoon at 1620h EAT. The higher reading from the two days was then recorded on a digital form. Additional location information was also collected to give context to the sound readings.

3.3.3: Survey Design

The data collected from the secondary research was used to create closed-ended surveys for wider distribution. A copy of the digital questionnaire that was used to conduct the survey is available in the appendix section of this thesis. The questionnaire comprised of four multiple choice questions.

The survey was meant to facilitate frictionless collection of quantitative and qualitative data from larger groups of participants (Houston, 2023). It was distributed digitally. The purpose of the survey was threefold:

    i.   To collect age demographics.

   ii.   To collect data on prevalence of ambient noise sources

  iii.   To establish telecommuting behavior patterns.

A survey was selected as one of the data collection tools because it enabled the researcher to cheaply and efficiently collect data directly from many participants within a short amount of time. A larger population lends the study statistical power.

The survey was used to collect cross-sectional data during the research period. The survey was administered as a digital questionnaire in the month of April 2023. The researcher aimed to conduct the survey on 30 participants. The survey had polled 202 participants by its close at the end of April 2023.

3.4: TARGET POPULATION

3.4.1: Geographic information

Kenya is a country located in East Africa. Nairobi is a City which is the capital of Kenya and the area of study for this project. Nairobi has the highest number of households within the country with a resident population of 4,397,073 (CountryTrak, 2020). This figure is as at the last national census conducted in 2019.

With the devolution of the Kenyan government functions in the year 2010, sub counties were created. These sub counties are decentralized units that are used to provide healthcare, education, transportation and other services. While sub-counties' core function is provision of services and facilities (Office of the Attorney General, 2013), constituencies are more focused on administrative functions.

In urban areas of the country, sub-counties do not strictly coincide with constituencies as is the case in rural areas. Nairobi City has 17 constituencies, but 11 sub-counties. 8 of the 11 sub-counties have borders that coincide with constituencies as follows: Westlands, Lang'ata, Kibra, Kasarani, Makadara, Kamukunji, Starehe and Mathare.
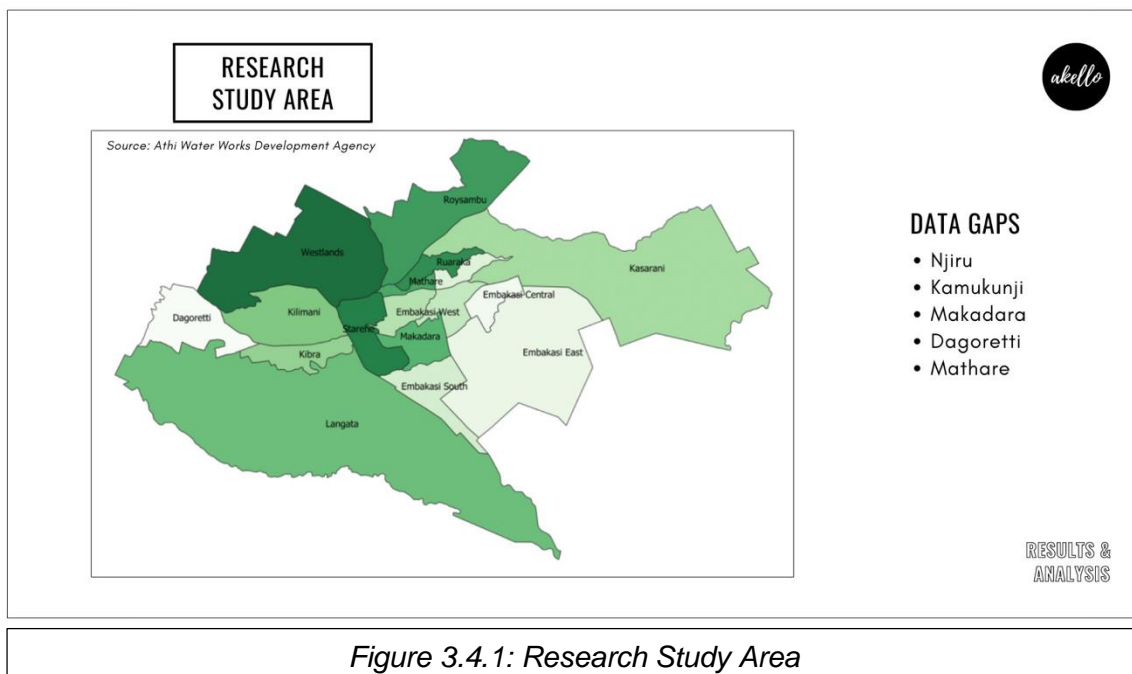

Figure 3.4.1: Research Study Area

Nairobi's sub-counties and their population numbers are as follows (Ambani, 2019):

Table 3.4.1: Nairobi's Sub-Counties	
Sub-County	**Population (persons)**
Lang'ata	197,489
Njiru	626,482
Mathare	206,564
Embakasi	988,808
Westlands	308,854
Dagoretti	434,208
Makadara	189,536
Kamukunji	268,276
Kibra	189,777
Kasarani	780,656
Starehe	210,423

Since this thesis addressed a service issue and not an administrative one, the sub counties were used to delineate the sample areas. For the fieldwork, a household was selected in each Nairobi sub-county based on convenience sampling. The whole of Nairobi county was the sample area for the survey.

3.4.2: Demographic information

The participants in the survey were home-based telecommuters living in Nairobi. The study focused on working adults who were categorized into three demographic cohorts which were latchkey generation, millennials and centennials/zoomers.

The participants in the fieldwork were residents of Nairobi. They were technologically literate and had experience with home-based telecommuting. Through convenience sampling, the researcher identified participants in six of Nairobi's eleven sub-counties. The researcher was unable to identify participants in Mathare, Makadara, Kamukunji and Dagoretti sub-counties. These five areas represent the study's data gaps.

3.5: DATA ANALYSIS METHODS

3.5.1: Statistical Analysis

Inferential analysis was used to draw general conclusions about a population based on patterns observed in the sample (Farren, 2014). These were age distribution and work from home patterns of telecommuters in Nairobi. The data sets were presented as pie charts.

Measures of central tendency were recorded for data sets where it applied. These measures are used to quickly assess the validity of each data set.

3.5.2: Content Analysis

Content analysis involves examining and quantifying presence of certain concepts. Because Design Thinking was being utilized to formulate a solution to the problem statement, the use of content analysis was prudent. This data analysis method reveals consumer behavior trends allowing the solution to be optimized to fit the majority needs of the market (Calzon, 2023).

Content analysis helps the researcher to make reliable conclusions. It was used to interpret survey results thereby outlining the characteristics of the user persona. Content analysis was used to establish telecommuting patterns and common sources of noise in the home.

3.6: ETHICAL CONSIDERATIONS

Ethics can be described as the science of conduct. It aims to establish a moral base by distinguishing between right and wrong (Krishnamurthy, 2011). Ethics investigates the morality of the researcher's actions to determine whether they are desirable or not (Bartneck et al, 2021). It is important for research methods to cater to philosophies of ethics and moral behavior. This practice serves to protect the communities within which research is being conducted by reducing the likelihood of researcher malpractices (Resnik, 2020). The ethical considerations taken into account for this project were plagiarism, honesty and consent.

PLAGIARISM	HONESTY	CONSENT
Referenced ideas were only included with proper acknowledgement.	Research information was presented truthfully even when it was unfavorable.	Informants participated willingly and could withdraw at any time.
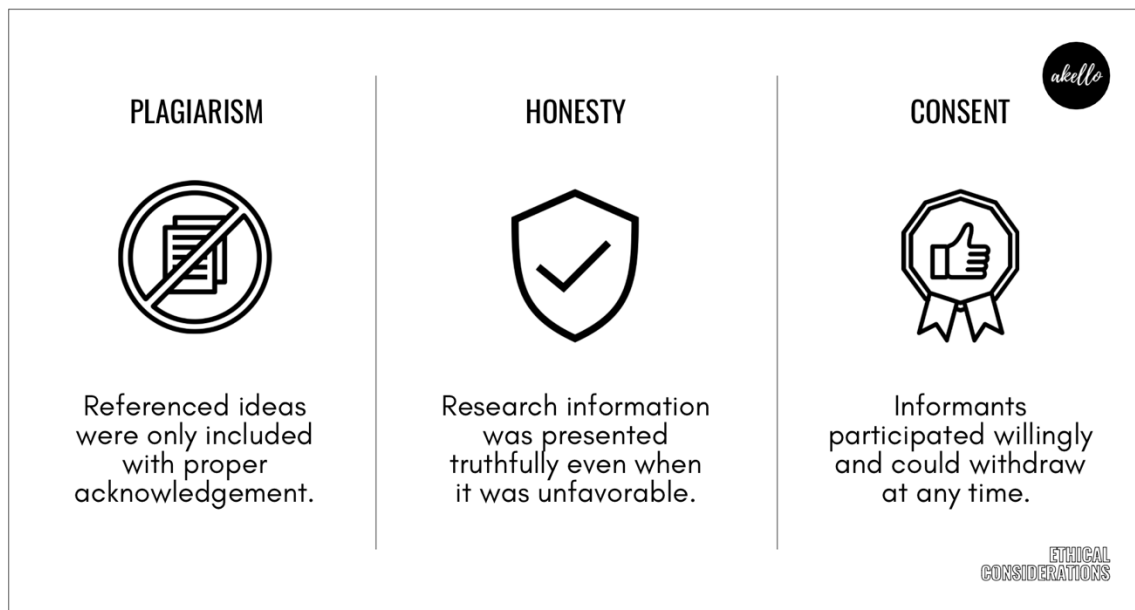
Figure 3.6.1: Ethical Considerations

3.6.1: Avoidance of Plagiarism

The University of Oxford, UK defines plagiarism as "Presenting someone else's work or ideas as your own, with or without their consent, by incorporating it into your work without full acknowledgement." The researcher only included referenced ideas with proper acknowledgement.

Intentional plagiarism is considered to be academic misconduct (Roka, 2017). Unintentional plagiarism is likely to occur due to human error, but can be detected by checking software and subsequently corrected. Auto-plagiarism can arise when an author submits work that has been previously submitted without referencing it clearly (Mehić, 2013).

To ensure the validity and reliability of the study, most journals and academic institutions have a plagiarism threshold (Fyvie, 2020). The study was ran through Turn-It-In to ensure it met this threshold.

3.6.2: Upholding Honesty

Fabrication of information during research can be tempting for reasons including pressure to meet deadlines, data gaps and steering desired results (Fanelli et al, 2017). It is the responsibility of the researcher to ensure that data collected, data analysis and research methods are true (Resnik, 2020). All research was presented truthfully to the best knowledge of the researcher.

3.6.3: Seeking Consent

Informed consent and voluntary participation were guiding principles when executing this study. Not only was this an ethical matter, but it was also a measure to avoid legal action (Skidmore, 2021) which could prove costly on an already limited budget. Informants were made aware of how their data would be used. Their privacy was not be infringed upon without their express consent. This consent was not be tricked or coerced out of them. Participants were given the option to withdraw from the study at any time. Where possible, the confidentiality of the persons being studied was maintained.

3.7: SUMMARY

Table 3.7.1: Research Design	
RESEARCH DESIGN	
Research Philosophy	Pragmatism
Research Type	Descriptive
Research Strategy	Design Thinking
Sampling strategy	Non-probability sampling (Convenience, Snowball)

Logic of Enquiry: Hybrid research

Types of Data Collected: Nominal, Ordinal, Discrete, Continuous

Data Collection Methods: Pre-test, Fieldwork, Survey

Data Analysis Methods: Statistical Analysis, Content Analysis

CHAPTER 4.0: RESULTS & ANALYSIS

4.1: INTRODUCTION

The goal of this study was to innovate in the Acoustic Interior Design field.

The three research objectives were as follows:

i.   To establish the pain points of residential video call users in Nairobi.

ii. To identify existing interior design solutions for acoustics during video calls.

iii. To design an acoustic conceptual interior design product that improves domestic video call quality.

Primary data was collected through a survey and field work. In addition to uncovering demographic patterns, the primary data identified the acoustic pain points of home-based telecommuters. This addresses the second research question.
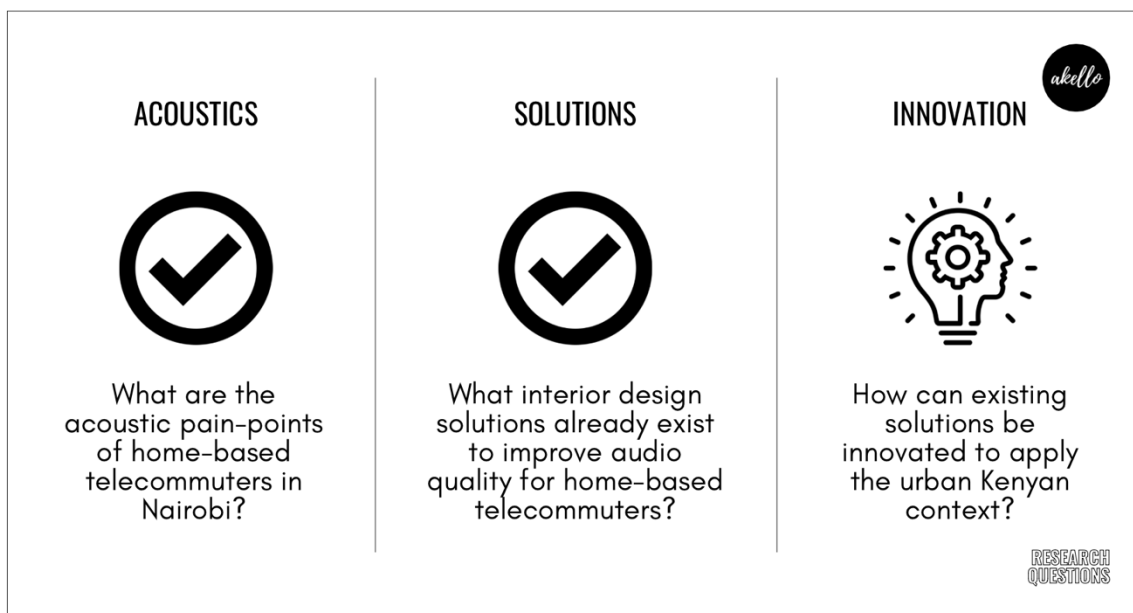
Figure 4.1.1: Research Questions Checklist II

The results obtained during the primary research are outlined in this chapter. Also included are basic statistical analyses of the primary data.

4.2: COLLECTED DATA

4.2.1: Pre-test Results

The pre-test was conducted during the month of February in the year 2023. It was conducted in the researcher's residence. Sound levels were recorded using a mobile application.

Participants: 1 person

Method: measurements using a sound recording app

Data Gaps: Nil

Location: Kibra Sub-County, Nairobi County, Kenya

Table 4.2.1: Pre-test Results				
Date	**Time**	**Low**	**High**	**Average**
WED **08 FEB**	Morning	29.7	60.1	44.9
	Afternoon	41.3	61.8	51.6
THUR **09 FEB**	Morning	38.3	55.9	47.1
	Afternoon	37.7	60.3	49.0
FRI **10 FEB**	Morning	40.4	51.3	45.9
	Afternoon	37.6	64.8	51.2
SAT **11 FEB**	Morning	37.9	51.0	44.5
	Afternoon	34.4	52.0	43.2
SUN **12 FEB**	Morning	31.0	48.0	39.5
	Afternoon	20.3	33.4	26.9
MON **13 FEB**	Morning	29.1	52.5	40.8
	Afternoon	43.4	75.2	59.5
TUE **14 FEB**	Morning	33.7	58.8	46.3
	Afternoon	52.5	65.1	58.8
WED **15 FEB**	Morning	36.6	52.1	44.4
	Afternoon	38.3	53.2	45.8
THUR **16 FEB**	Morning	38.2	44.1	41.2
	Afternoon	38.9	56.2	47.6
FRI **17 FEB**	Morning	37.6	51.1	44.4
	Afternoon	46.4	61.6	54.0

SAT **18 FEB**	Morning	28.3	49.2	38.8
	Afternoon	36.9	69.1	53.0
SUN **19 FEB**	Morning	33.0	50.3	41.7
	Afternoon	37.9	56.0	47.0
MON **20 FEB**	Morning	33.8	49.4	41.6
	Afternoon	42.0	64.2	53.1
TUE **21 FEB**	Morning	33.7	49.8	41.8
	Afternoon	39.2	67.8	53.5

4.2.2: Fieldwork Results

The fieldwork was conducted during the month of April in the year 2023. It was conducted in the various residences in Nairobi County. Sound levels were recorded using a mobile application.

Participants: 7 persons

Method: measurements using a sound recording app

Population: Home-based telecommuters living in Nairobi

Data Gaps: Mathare, Kamukunji, Njiru, Makadara and Dagoretti Sub-Counties

Location: Starehe, Embakasi, Kasarani, Kibra, Westlands and Lang'ata Sub-Counties

	Table 4.2.2: Fieldwork Results	
	NAIROBI SUB COUNTY	**MAXIMUM NOISE LEVEL (dB)**
1	Starehe	96
2	Embakasi	103
3	Kasarani	79.8
4	Starehe	75
5	Embakasi	83
6	Starehe	53
7	Kibra	69.4
8	Westlands	51
9	Lang'ata	31

4.2.3: Survey Results

The survey was conducted during the month of April in the year 2023. It was conducted by means of a questionnaire. Results were collected digitally.

The questionnaire had a total of four questions. Three of the questions were multiple choice with the option to pick only one answer. One question was multiple choice, but allowed participants to select all answers that applied.

Participants: 202 persons

Method: digital questionnaire

Population: Home-based telecommuters living in Nairobi

Data Gaps: Nil

Location: Nairobi County, Kenya

Table 4.2.3: Survey Results I	
DEMOGRAPHIC COHORT	**% OF PARTICIPANTS**
Millennial	31.2%
Centennial/Zoomer	30.7%
Latchkey Generation	27.2%
Boomer	6.9%
Prefer not to say	4.0%

Table 4.2.4: Survey Results II	
TELECOMMUTING FREQUENCY	**% OF PARTICIPANTS**
Three or more times a week	58.4%
Once a week	30.3%
Occasionally	10.9%
Never	0.5%

Table 4.2.5: Survey Results III	
TELECOMMUTING STYLE	**% OF PARTICIPANTS**
Designated desk space	33.7%
Wherever space is available	66.3%

Participants were allowed to select all answers that applied for this question. Some participants selected multiple responses.

Table 4.2.6: Survey Results IV	
TELECOMMUTING NOISE SOURCES	**NUMBER OF PARTICIPANTS**
Noise from other inhabitants	131
Noise from household appliances	100
Noise from outside	77

4.3: DATA ANALYSIS

By analyzing the results of the primary research, user patterns can be identified. Synthesis is then conducted to define the pain-points of home-based telecommuters in Nairobi.
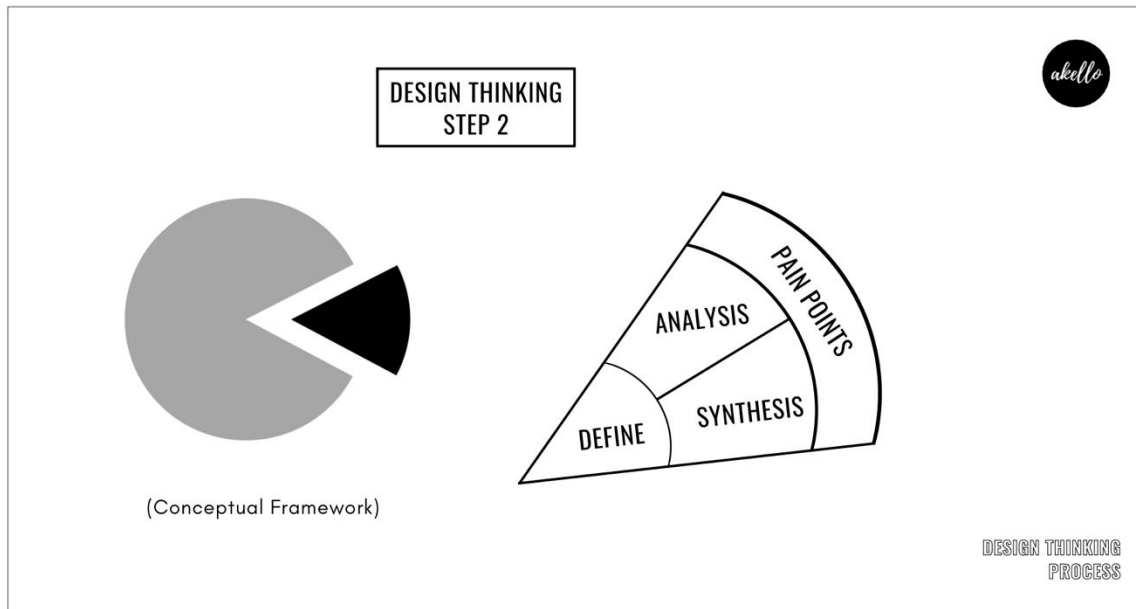
Figure 4.3.1: Design Thinking Process II

For ease of analysis, the primary data collected was summarized in the table below. Each research activity was then analyzed separately.

ACTIVITY	STUDY TYPE	DATA TYPE
Table 4.3.1: Data Collected		
Pre-test	Quantitative	Continuous
Fieldwork	Qualitative	Nominal
	Quantitative	Continuous
Survey	Qualitative	Nominal & Ordinal
	Quantitative	Discreet

4.3.1: Pre-test Analysis

The data collected was continuous quantitative data. High and low readings were averaged as shown in the pre-test results table. The average readings were then analyzed to collect measures of central tendency as below.

Mode: 44.4 dB
Median: 45.4 dB
Mean: 46.1 dB

4.3.2: Fieldwork Analysis

Continuous quantitative data was collected on sound levels in Nairobi residential homes. Only high readings were recorded unlike in the pre-test. The high readings were then analyzed to collect measures of central tendency.

Mode: N/A
Median: 75.0 dB
Mean: 71.2 dB

Nominal qualitative data was collected on location and telecommuting style. Location information was used to identify data gaps. Telecommuting style data was used to build the user persona.

Data Gaps: Mathare, Kamukunji, Njiru, Makadara and Dagoretti Sub-Counties

4.3.3: Survey Analysis

Content analysis was used to identify recurrent themes from the survey data sets. The data collected was presented as pie charts and a histogram. Content analysis was used because it is suitable for both qualitative and quantitative data.
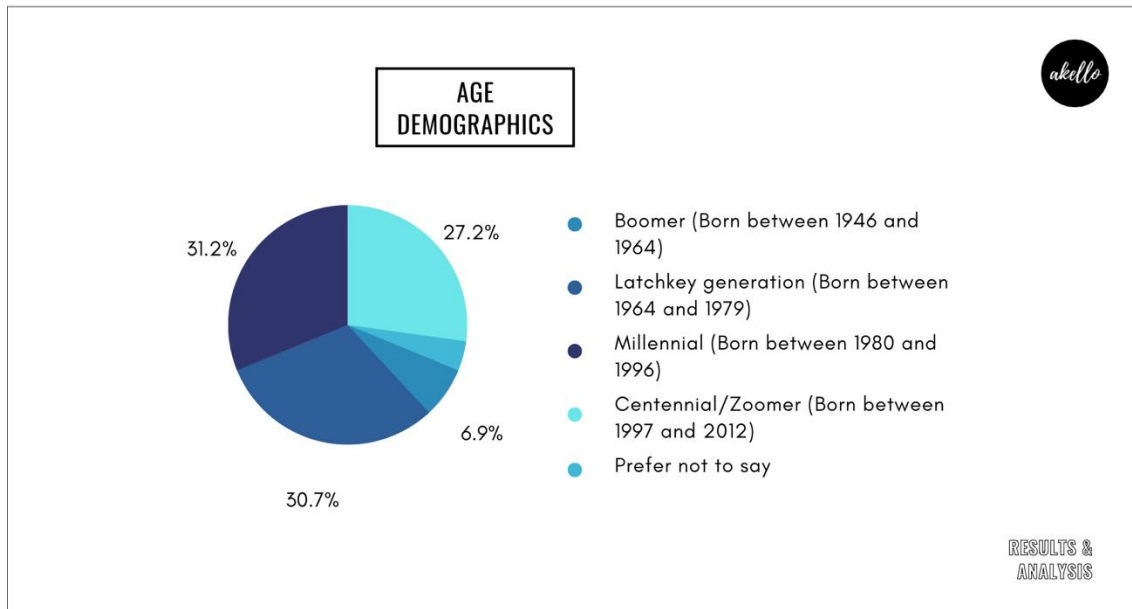
Figure 4.3.2: Age Demographics Results

The age distribution of the sample surveyed was almost evenly spread between the latchkey, millennial and centennial/zoomer generations.
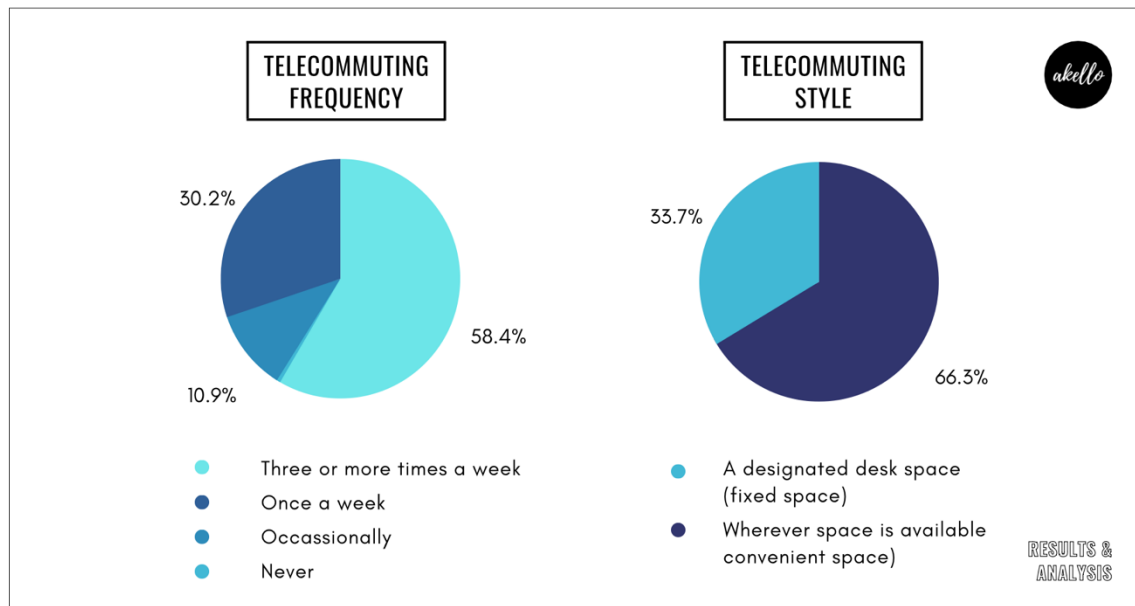
Figure 4.3.3: Telecommuting Results I

88.6% of participants surveyed work from home at least once a week. 66.7% of home-based telecommuters work wherever space is convenient in the home.

It is known that some participants selected multiple sources of noise. Therefore this data set is best analyzed using a histogram.
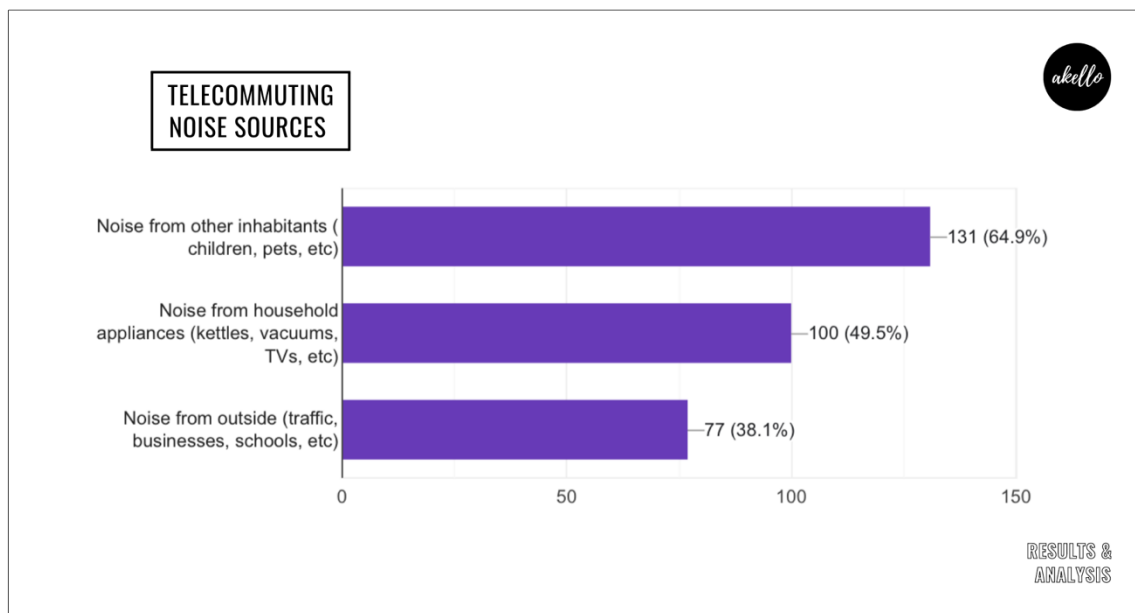
Figure 4.3.3: Telecommuting Results II

Noise from other inhabitants (such as children and pets) was the most prevalent source of noise while home-based telecommuting. 131 out of 202 participants surveyed selected this pain-point.

4.3.4: Summary

The analyzed data was used to create a user persona. This persona embodies home-based telecommuters in Nairobi and their pain-points.
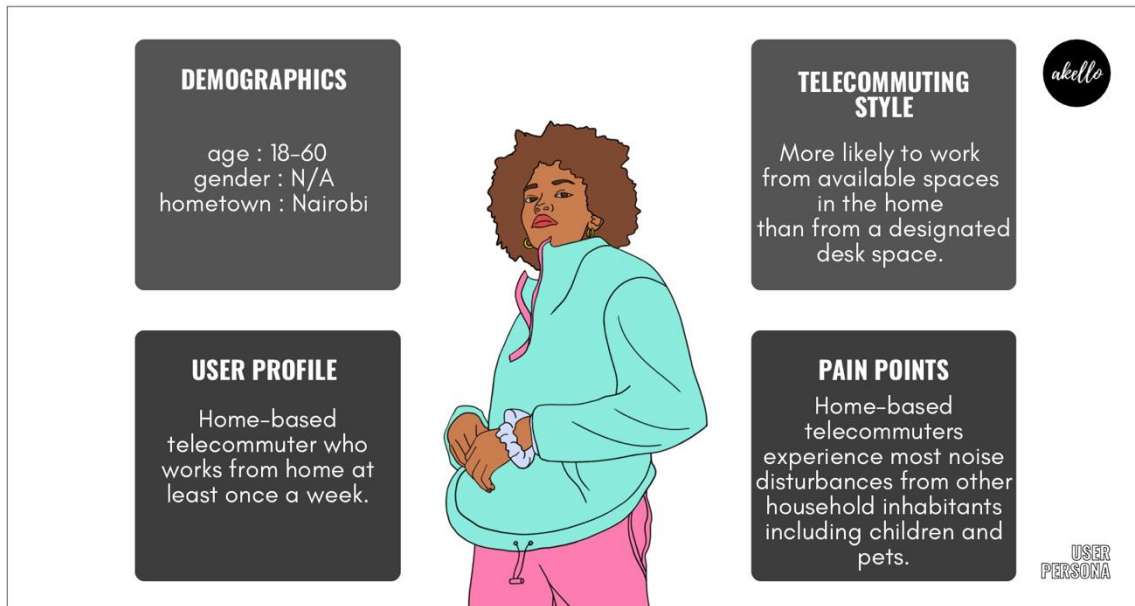
Figure 4.3.4: User Persona

The representation of the user persona and their pain-points marks the completion of the first two milestones. Project management information is available in the appendix section of this thesis.

CHAPTER 5.0: DISCUSSION

5.1: INTRODUCTION

At this point of the study, step one and two of the Design Thinking process outlined in the Conceptual Framework have been carried out. This chapter aims to ideate a possible solution tailored to the identified user persona.
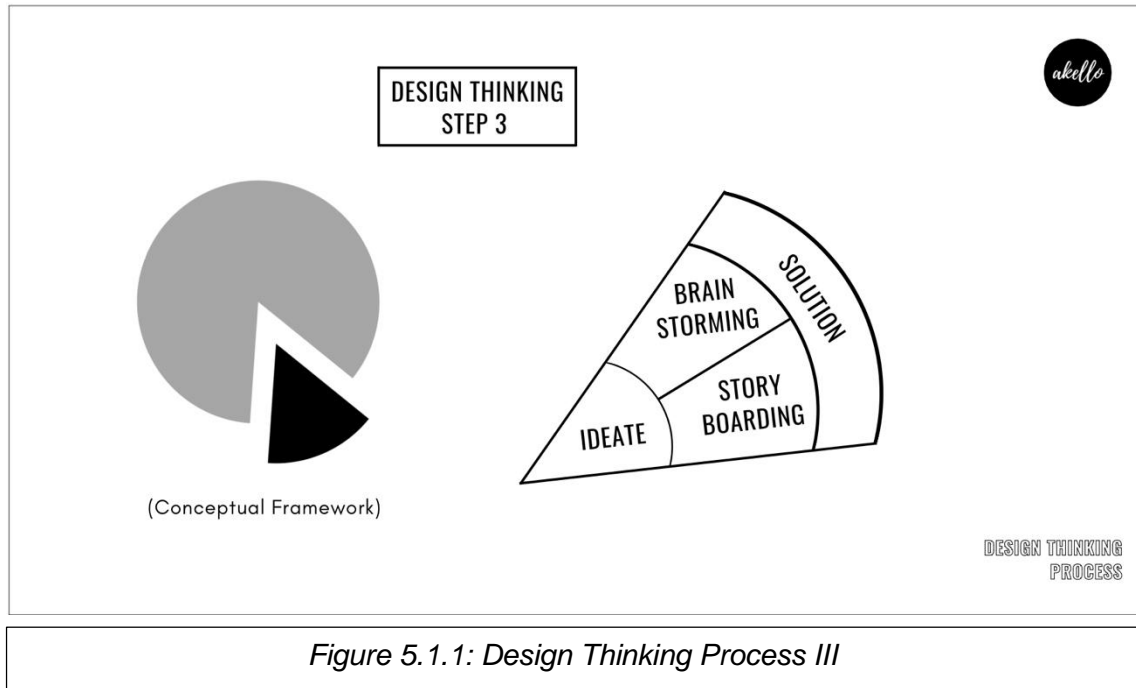
Figure 5.1.1: Design Thinking Process III

The project goal was innovation. This was narrowed down to materials innovation, labor innovation and price innovation. All three can be achieved by home-based telecommuters using recycling materials to build an acoustic product.

Interpretivism was applied to carry out the ideation of the product. This simply means that ideas are limited to the researcher's scope of expertise.

5.2: IDEATION PROCESS

The two methods selected for ideation were brainstorming and storyboarding. The selection choices were based on the researcher's abilities at the time of the study.

5.2.1: Brainstorming

Brainstorming was used as an exercise to recall the researcher's skill base and match these skills to innovation attempts. The skills were taught during the duration of the Master's Degree Program. Two areas of study with suitable grasp of concepts were required for each innovation attempt. Grasp of concepts was demonstrated by the grade awarded for each unit.

The results of the brainstorming exercise were as follows:

Table 5.2.1: Innovation Process Mapping		
Materials Innovation: use of sustainable design materials.		
Course Code	Course Title	Grade
BDS 511	Design Materials and Process	B
BDS 524	Furnishing Design	B
Labor Innovation: creation of local employment opportunities.		
Course Code	Course Title	Grade
BDS 505	History of Design	A
BDS 507	East African Design	B
Price Innovation: affordability of solution.		
Course Code	Course Title	Grade
BDS 503	Design Management	B
BDS 542	Design Practice	C

Recall that this research adopted interpretivism as one of its philosophies. Interpretivism allows for the researcher to interpret the collected data based on experience. The brainstorming allowed the researcher to lay out the skills taught during the duration of the Master's Degree. Interpretivism was used to apply said skills to the innovation attempt.

5.2.2: Storyboarding

A storyboard is a visual representation of a plan or an idea. It illustrates step by step how the solution unfolds. The storyboard was used as a roadmap to conceptualize a product that solves the problem statement.
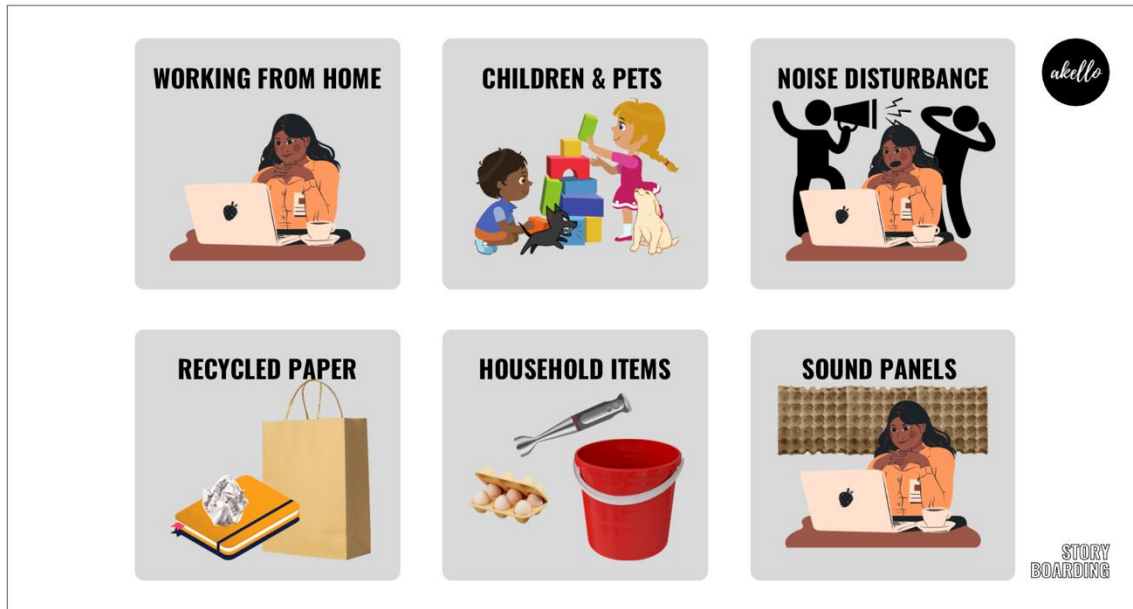
Figure 5.2.2: Storyboard

The storyboarding process was carried out digitally. The story block on the top half of the diagram represented the problem. The story block on the bottom half of the diagram represented the idea to solve it.

The idea was to create a wall mounted sound panel from recycled paper using items found around the home. For ease of reference the product was given branding. This product's brand name is ALTO. ALTO will be created by the telecommuter by themselves to cover the labor innovation aspect of this study.

5.3: PRODUCT DETAILS

ALTO is a lightweight panel made from recycled materials and household items. Once again, interpretivism is used as a philosophy. Concept product ALTO is designed based on the
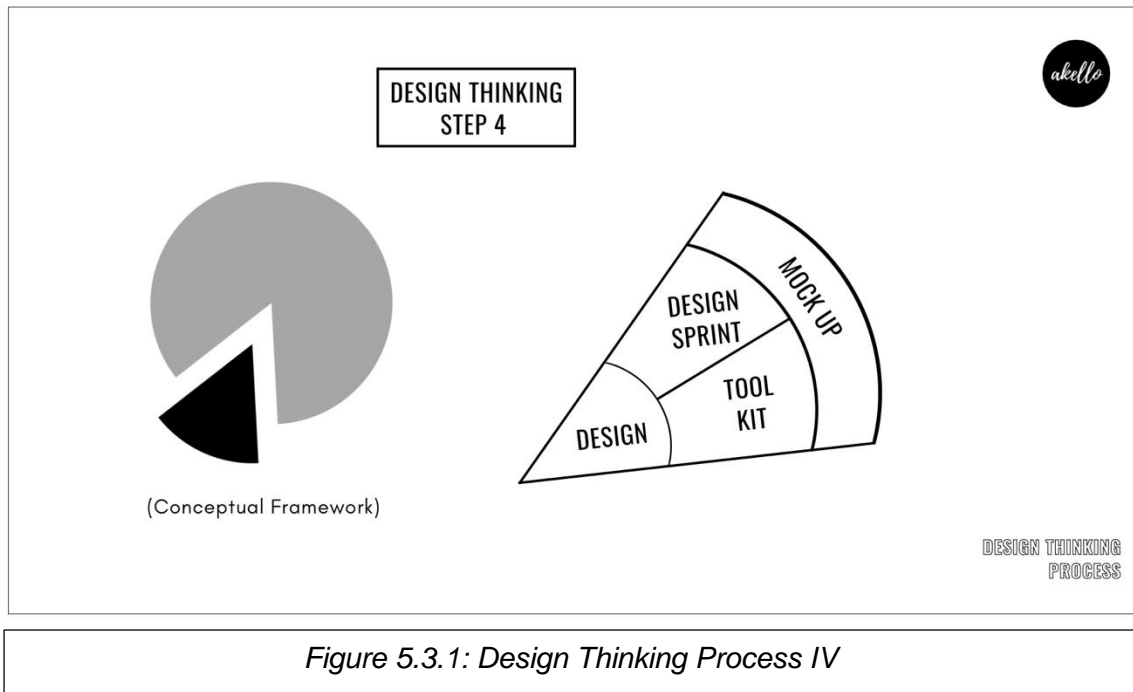
Figure 5.3.1: Design Thinking Process IV

researcher's knowledge.

The design is carried out bearing in mind the tool kit visualized in the storyboard. It includes an immersion blender, a plastic bucket and a plastic egg tray. It was designed to be wall mounted using a stick on hook. The stick on hook is friendlier than a drill mount since it can be peeled off when relocating. The wall mount was designed to allow installation anywhere in the house.

5.3.1: Design Details

Product Dimensions: The dimensions of concept product ALTO are constrained by the plastic egg tray being used as a mold.

Product Material: The researcher recommends using recycled paper to make ALTO.

Product Production: The paper is soaked in a bucket of water and then shredded with the immersion blender to make a putty. The resultant putty is pressed into the egg tray molds at a 10mm thickness, then allowed to dry. Dried panels are de-molded and then wall mounted. The suggested rate of production is three panels at a time. By keeping the output low, the user will find curing spaces around the home more easily.

CHAPTER 6.0: CONCLUSION

6.1: INTRODUCTION

ALTO is a conceptual product. A low fidelity prototype would allow the designer to visualize physical characteristics of the concept product. A high fidelity prototype would allow the designer to visualize functional characteristics of the concept product.

To conclude this study, the remaining steps of the Design Thinking process are outlined. It is the researcher's belief that the outcome could be a a tangible item. All conclusions are limited to the researcher's knowledge.

6.2: PROTOTYPING

The fifth step of the Design Thinking process is prototyping. A high quality digital model can be created using 3-D software such as Blender. These renders are the first manifestations of the concept product ALTO. A physical scale model can also be used for the low fidelity prototype. This model can be made from card stock or straw board.
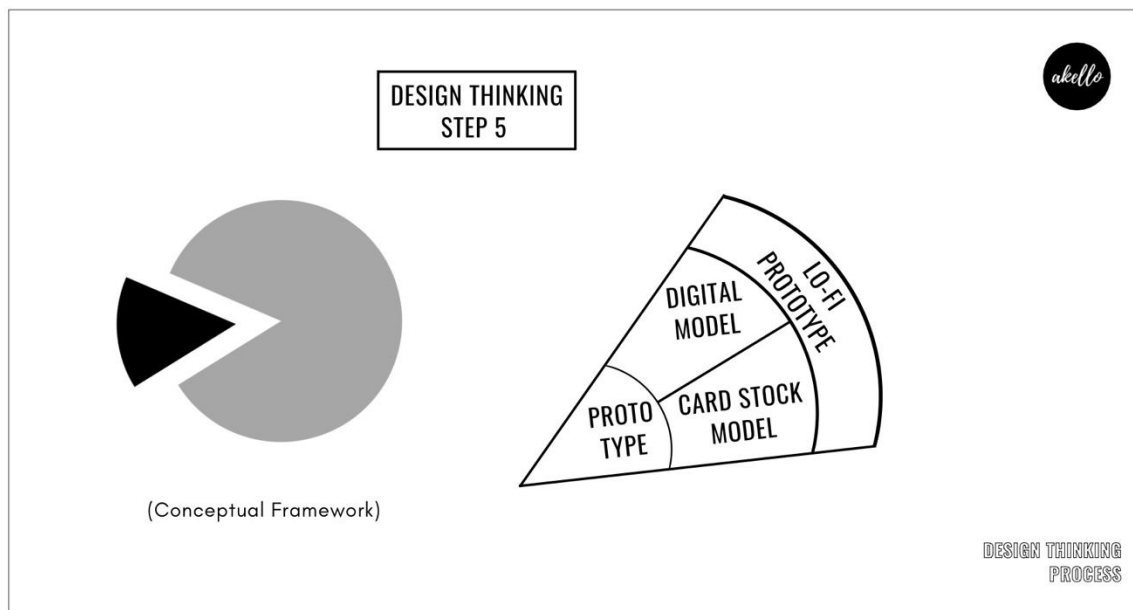
Figure 6.2.1: Design Thinking Process V

The low fidelity prototype can be used to make improvements to concept product ALTO before attempting to create a high fidelity prototype.

6.3: VALIDATION

For validation, a high fidelity prototype should be made using the steps outlined in the product details and referencing the low fidelity prototype. The high fidelity prototype is a tangible product which can be tested in an acoustic lab to determine its noise reduction capacity. The same prototype can be distributed to a small group of users for feedback purposes. Their user feedback can be collected using a Likter scale.
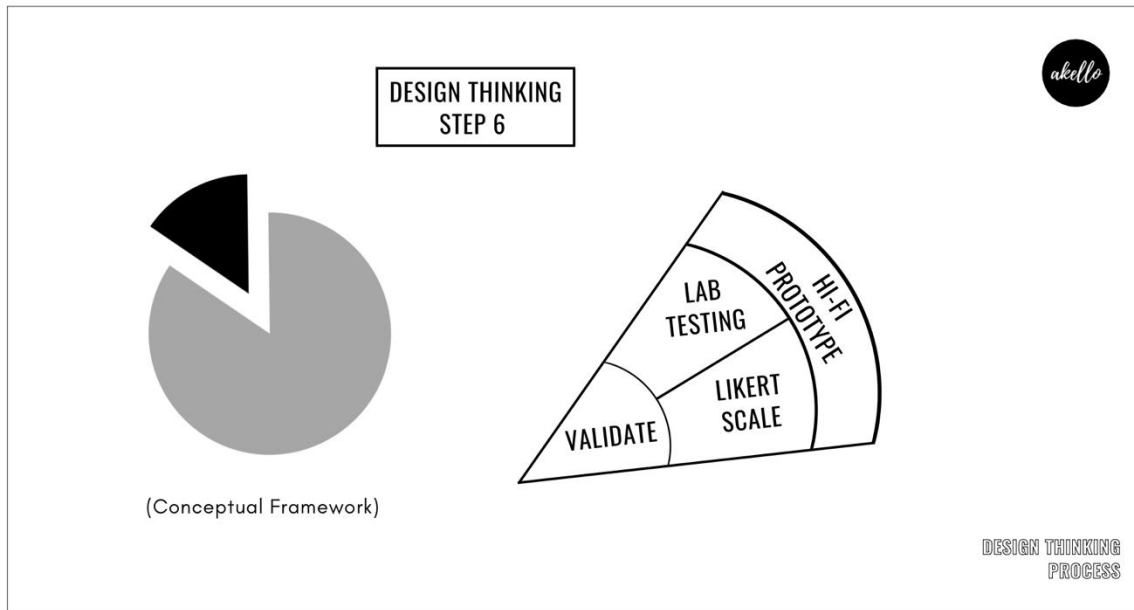
Figure 6.3.1: Design Thinking Process VI

The completion of the validation step of the Design Thinking cycle should result in either a market ready product or a product that needs improvements. In case of the latter, the Design Thinking cycle can be repeated as shown in the conceptual framework. The beauty of this cyclical nature is that as many iterations as needed can be carried out.

This thesis documents the use of the Design Thinking process to solve an audio quality issue for home-based telecommuters in Nairobi. The study was successful.

CHAPTER 7.0: REFERENCES

7.1: IMAGE SOURCES

7.1.1: Chapter 1.0 Images

i. Figure 1.2.1: data sourced from
    https://www.uschamberfoundation.org/sites/default/files/article/foundation/MillennialGeneration.pdf, visual generated by author.

ii. Figure 1.2.2: data sourced from https://statista.com/statistics/1122987/change-in-remote-work-trends-after-covid-in-usa/#statisticContainer, graph generated by author.

iii. Figure 1.2.3: data sourced from https://www.pewresearch.org/social-trends/2022/02/16/covid-19-pandemic-continues-to-reshape-work-in-america/, visual representation generated by author.

iv. Figure 1.3.1: data sourced from https://www.statista.com/statistics/1246368/communication-services-usage/, graph generated by author.

v. Figure 1.3.2: https://maps-kenya-ke.com/kenya-constituencies-map

vi. Figure 1.3.3: data sourced from https://www.macrotrends.net/countries/KEN/kenya/unemployment-rate, graph generated by author.

vii. Figure 1.5.1: generated by author

viii. Figure 1.6.1: generated by author

7.1.2: Chapter 2.0 Images

i. Figure 2.1.1: generated by author

ii. Figure 2.2.1: generated by author

iii. Figure 2.2.2: generated by author

iv. Figure 2.2.3: https://www.sciencelearn.org.nz/resources/2816-sound-wave-interference

v. Figure 2.2.4: https://www.sciencelearn.org.nz/resources/2816-sound-wave-interference

vi. Figure 2.2.5: generated by author

vii. Figure 2.2.6: generated by author

viii. Figure 2.4.1: generated by author

7.2: REFERENCE LIST

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APPENDIX

APPENDIX 1: SUPERVISION LOGS

The table below catalogs contact points between the thesis author and the supervisors.

	MEETING TOPIC	SUPERVISOR	TYPE	DATE
1	Concept note presentation	**Dr. Collins**	Digital	**28 OCT 2022**
2	Thesis structure and format	**Dr. Collins**	Digital	**01 NOV 2022**
3	Project proposal presentation	**Dr. Collins**	On site	**04 NOV 2022**
4	Literature review guidelines	**Dr. Collins**	Digital	**18 NOV 2022**
5	Tuesday check-in	**Dr. Collins**	E-mail	**22 NOV 2022**
6	Design research and digital research methods	**Dr. Betty**	Digital	**25 NOV 2022**
7	Tuesday check-in	**Dr. Collins**	E-mail	**03 JAN 2023**
8	Literature review presentation	**Dr. Collins**	On site	**13 JAN 2023**
9	Literature review presentation	**Dr. Betty**	On site	**13 JAN 2023**
10	Tuesday check-in	**Dr. Betty**	E-mail	**24 JAN 2023**
11	Tuesday check-in	**Dr. Betty**	E-mail	**31 JAN 2023**
12	Brief update	**Dr. Collins**	On-site	**03 FEB 2023**
13	Brief update	**Dr. Betty**	E-mail	**03 FEB 2023**
14	Status update	**Dr. Collins**	E-mail	**08 FEB 2023**
15	Status update	**Dr. Betty**	E-mail	**08 FEB 2023**
16	Literature review feedback	**Dr. Betty**	E-mail	**23 FEB 2023**
17	Methodology review	**Dr. Collins**	E-mail	**21 MAR 2023**
18	Methodology guidelines	**Dr. Collins**	On-site	**19 APR 2023**
19	Methodology guidelines	**Dr. Betty**	On-site	**19 APR 2023**
20	Status update	**Dr. Collins**	E-mail	**27 APR 2023**
21	Thesis defense	**Dr. Betty**	On-site	**12 MAY 2023**
22	Thesis defense	**Dr. Collins**	On-site	**12 MAY 2023**
23	Results & Analysis guidelines	**Dr. Collins**	On-site	**16 MAY 2023**
24	Thesis submission	**Dr. Collins**	E-mail	**01 JUN 2023**
25	Thesis submission	**Dr. Betty**	E-mail	**01 JUN 2023**

APPENDIX 2: PRIMARY DATA COLLECTION ASSETS

Appendix 2.1: List of Areas in Nairobi's Sub-Counties

NAIROBI SUB-COUNTIES		
	Sub County	Areas and Estates
1	Starehe	Landi Mawe, Nairobi Central, Pangani, Muthurwa, Ngara East, Ngara West, Hazina, Mukuru Kayiaba, Railways, Kiwanjani, Jamhuri, Tetra Pak, Balozi, Kijijini, Fuata Nyayo, CBD, Ziwani, Kariokor
2	Mathare	Huruma, Mlango Kubwa, Kiamaiko, Daima, Mabatini, Kiboro, Bondeni, Kibichoi, Ngei, Ndurumo, Central, Madoya, Gitathuru, Mashimoni, Kosovo, Ngetto, Metameta, Kwa Munene, Castle, Ndururumo, Kyamutisia
3	Kibra	Kibera, Mbagathi, Mashimoni, Upper Hill, Woodley, Kambi Muru, Golf Course, Kenyatta Market, Ngumo
4	Langata	Kareng'ata, Wilson, Kiang'ombe, Karen, South C, Nyayo, Otiende, Nairobi West, Madaraka, Highrise, Mugumo-ini, Laini Saba, Makina, Mashimoni, Gatwekera, Kisumu Ndogo
5	Dagoretti	Kawangware, Uthiru, Riruta, Satellite, Upper Kabete, Kinoo, Mutu-ini, Ng'ando, Ruthimitu, Waithaka, Kabiro, Gatina, Race Course, Lenana
6	Embakasi	Industrial Area, Umoja, Mowlem, Dandora, Kwa Njenga, Kwa Reuben, Pipeline, Kware, Matopeni, Komarock, Fedha, Tena, Makadara, EPZ, Tassia, Nyayo, Imara Daima, Savanna, Mihango, Utawala
7	Kamukunji	Pumwani, Eastleigh North, Eastleigh South, Shauri Moyo, Bahati, California, Airbase
8	Kasarani	Roysambu, Ruaka, Clay City, Mwiki, Garden Estate, Ridgeways, Zimmerman, Kahawa, Kahawa West, Githurai, Utalii, Babadogo, Lucky Summer, Korogocho, Runda
9	Makadara	Makongeni, Harambee, Viwandani, Maringo, Hamza, South B, Donholm, Lunga Lunga, Kayaba, Makadara
10	Njiru	Kayole, Kariobangi South, Dandora, Ruai, Saika, Njiru, Kamulu
11	Westlands	Kitisuru, Kangemi, Kyuna, Parklands, Highridge, Loresho, Karura, Mountain View, Kilimani, Lavington, Muthangari, Maziwa, Kileleshwa

Appendix 2.2: Data Collection Draft

Based on the research questions, the data that needed to be collected was represented. These draft questions were then separated into a survey and fieldwork for research.

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akello

RESEARCH QUESTIONNAIRE

Name: am akello
Mail: eng.akello@gmail.com
Phone: +254 736 044 614

Background information: This questionnaire has been formulated to collect information on sound levels in the home. The information will be used to improve video call quality for telecommuters in Nairobi. The field of research is Acoustic Interior Design.

1. **Which demographic age group do you belong to?** (Pick one)
   ☐ Boomer (Born between 1946 and 1964)
   ☐ Latchkey generation (Born between 1965 and 1979)
   ☐ Millennial (Born between 1980 and 1996)
   ☐ Centennial/Zoomer (Born between 1997 and 2012)
   ☐ Prefer not to say

2. **Where in Nairobi is your area of residence?**
   (For privacy reasons, do not give your exact address. Indicate the name of the nearest landmark OR main road to your residence. Refer to Google Maps for accuracy.)

   ....
   ....

3. **What is the highest decibel sound reading in your residence?**
   (Download Decibel Pro: dB Sound Level Meter (for Android) OR Sound Meter: dB Meter (for iOS) onto your phone or iPad. Use the app to measure the sound levels in your work area on a Friday or a Saturday at 1620h EAT. Record the maximum noise reading. If both days are measured, record the higher reading of the two days.)

   ....

4. **Where in your residence do you telecommute from?** (Pick one)
   ☐ A designated desk space (fixed space)
   ☐ Wherever space is available (convenient space)

5. **Which of the following noise sources are present in your residence while you are telecommuting?** (Pick all that apply)
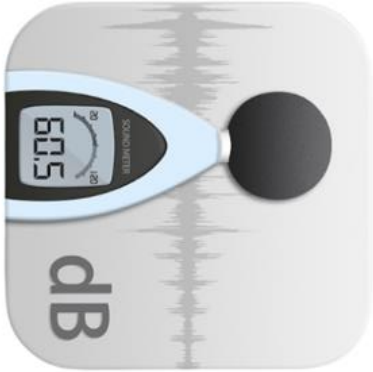   ☐ Noise from other inhabitants (noise from children, pets, etc)
   ☐ Noise from household appliances (noise from kettles, vacuums, televisions, etc)
   ☐ Noise from surrounding areas to the residence (noise from traffic, schools, businesses, etc)

Appendix 2.3: Survey Questionnaire

SURVEY QUESTIONNAIRE

Telecommuting Questionnaire

This questionnaire has been formulated to collect **qualitative data** about home-based telecommuting in Nairobi. The information will be used to improve video call quality for telecommuters in Nairobi. The field of research is Acoustic Interior Design.

Telecommuting is working/learning on the internet using a device such as a phone, tablet or computer. How often do you telecommute from home? (Pick one) *

○ Three or more times a week

○ At least once a week

○ Occasionally

○ Never

Where in your home do you telecommute from? (Pick one) *

○ A designated desk space (fixed space)

○ Wherever space is available (convenient space)

Which of the following sources of noise are present in your home while you are telecommuting? (Pick all that apply)

B I U ⊖ ✗

☐ Noise from other inhabitants (children, pets, etc)

☐ Noise from household appliances (kettles, vacuums, TVs, etc)

☐ Noise from outside (traffic, businesses, schools, etc)

Which demographic age group do you belong to? (Pick one) *

B I U ⊖ ✗

○ Boomer (Born between 1946 and 1964)

○ Latchkey generation (Born between 1965 and 1979)

○ Millenial (Born between 1980 and 1996)

○ Centennial/Zoomer (Born between 1997 and 2012)

○ Prefer not to say

akello

DATA COLLECTION

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Appendix 2.4: Fieldwork Data Collection Software

APPENDIX 3: PROJECT MANAGEMENT

The researcher had a background in civil engineering with six years of work experience in the interior design field. The researcher's role in executing the project was as follows:

- **Concept Development:** after relevant data had been gathered, the researcher undertook to interpret this information and create a viable solution to the identified problem statement.
- **Project Management:** the researcher engaged in project management to solve the problem statement within the available time and within budgetary constraints.
- **Content Creation:** the researcher created visual output to explain the processes and results of the project.

Appendix 3.1: Project Milestones

By referring to the conceptual framework at the end of the literature review chapters, six project milestones were defined as demonstrated below:
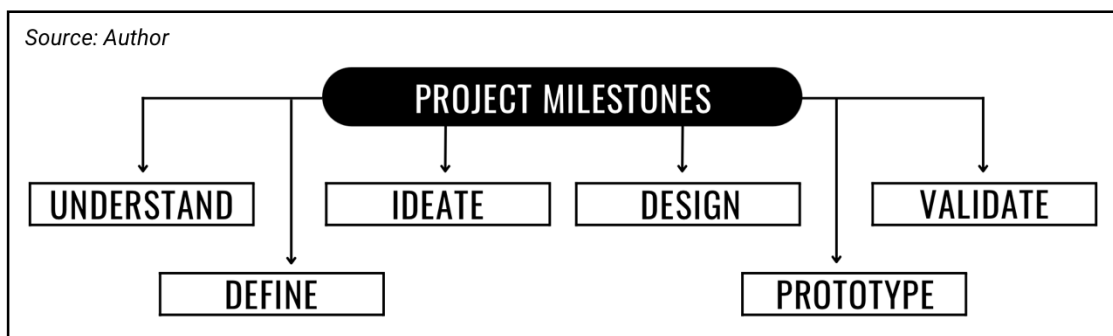
Figure 8.3.1: Project Milestones

Milestones represented key delivery points throughout the life cycle of the project. They provided tangible delivery points that structured the project into achievable objectives (Westland, 2021). They were also used as a tool for tracking project progress with the stakeholders.

Appendix 3.2: Project Management Methodology

The waterfall methodology is a project management approach that prioritizes linear and sequential progression of project tasks. For this particular methodology, the majority of the planning and documentation is conducted at the beginning of the project (Adobe, Communications Team, 2022). This allows better prediction of the project end-date and the project timelines. A waterfall project management model was adopted to execute this thesis from start to finish to cater to the tight timelines and modest budget.

Appendix 3.3: Stakeholder Analysis

The stakeholder analysis aimed to create a visual map of all the involved parties. It helped categorize the stakeholders based on their level of interest and their degree of influence (Grégoire, 2022). This determined how the researcher interacted with each stakeholder, for instance, the frequency of communication. The various stakeholders were placed into a power grid accordingly.
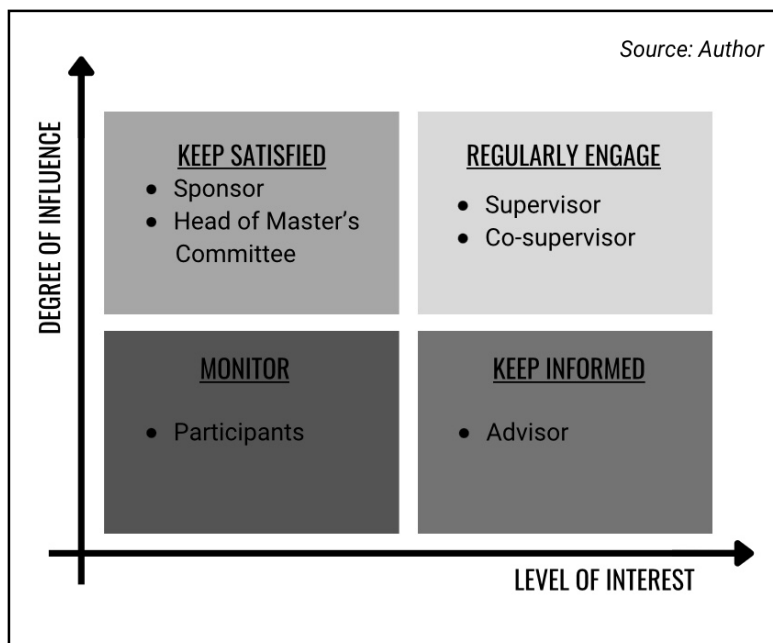
Figure 8.3.2: Stakeholder Analysis

Appendix 3.4: Project Timeline

The project management cycle refers to the phases that a project goes through from start to finish. These phases are initiation, planning, execution and closing (Bridges, 2023). The thesis research was scheduled to run for a duration of 10 months. It commenced in October 2022 and was scheduled to terminate in July 2023. Each project phase was assigned a duration on the timeline. The diagram below illustrates the various phases of the project.
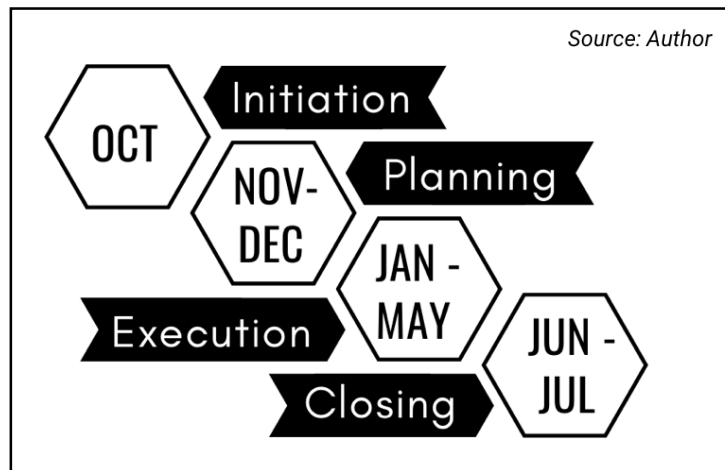
Figure 8.3.3: Project Timeline

Appendix 3.5: Project Budget

A project budget estimates the total costs needed to complete a time bound project (Foster, 2017). It is calculated by identifying the different categories of expenses that may come up during the duration of the project. Each category is then further broken down, and a description of each expense is provided (Kwon & Kang, 2018). The project budget for this thesis is represented as a Bill of Quantities (BoQ). The duration of this project is 10 months. Based on the researcher's industry experience, expense categories are identified as personnel, transportation, equipment, materials, services and overhead costs. A 10% contingency is then applied for unforeseen expenses.

Project Bill of Quantities (BoQ)

	CONCEPT PROJECT ALTO				
Item	DESCRIPTION	UNIT	QTY	RATE ($)	TOTAL
	A. PERSONNEL				
1	Researcher: person(s) conducting academic research. Responsible for concept development, project management and content creation.	man hours	1000	7	**$7,000.00**
2	Research assistant: person(s) supporting research activities. Responsible for literature searches, data management and document maintenance.	man hours	1000	5	**$5,000.00**
3	Field assistant: person(s) conducting data collection activities. Responsible for fieldwork including but not limited to photography, administration of research materials and participant management.	man hours	300	5	**$1,500.00**
4	Consultant: person(s) with expertise in particular subject areas. Responsible for provision of industry advice, proof reading findings and independent verification of facts.	man hours	200	13	**$2,600.00**
	B. TRANSPORTATION				
5	Ride share: a ride share account will be used to cover transportation of researcher and field assistant. Research assistant will be responsible for their own transport.	km	2000	0.5	**$1,000.00**

CONCEPT PROJECT ALTO					
Item	DESCRIPTION	UNIT	QTY	RATE ($)	TOTAL
	C. EQUIPMENT				
6	Research computer: to be in the possession of the researcher. Will be used for concept development, project management and content creation. The minimum system requirements for this device are: Intel i7 processor/Mac M1 processor, 16GB of RAM, a 1TB hard drive and a screen resolution of 1920x1080.	piece	1	1900	**$1,900.00**
7	Research tablet: to be in the possession of the research assistant. Will be used for literature searches, data management and document maintenance. The minimum system requirements for this device are: Android 5 operating system/iOS 15 operating system, 4GB of RAM, a 256GB hard drive and a screen resolution of 768x1024.	piece	1	1000	**$1,000.00**
8	Data collection tablet: to be in the possession of the field assistant. Will be used for field work and collection of data. The minimum system requirements for this device are: Android 3 operating system/iOS 11 operating system, 1.5GB of RAM, a 64GB hard drive and a screen resolution of 768x1024.	piece	1	600	**$600.00**
	D. MATERIALS				
9	Recycled paper: the cost of suitable waste paper delivered on site.	kilogram	400	0.2	**$80.00**
10	Water: clean, potable water delivered on site.	liter	200	0.5	**$100.00**
11	Plastic egg trays: clean and uncrushed empty egg trays.	piece	100	0.3	**$30.00**

CONCEPT PROJECT ALTO					
Item	DESCRIPTION	UNIT	QTY	RATE ($)	TOTAL
	E. SERVICES				
12	Project insurance: a short-term policy meant to cover any liabilities that may arise during the duration of the project.	monthly fee	10	150	**$1,500.00**
13	Subscriptions: premium apps used for project team communication (Slack), content creation (Adobe), document processing (Microsoft Office), data collection (dB Meter), etc.	monthly fee	10	80	**$800.00**
14	Stationery: pens, notebooks, rubber stamps and other such items necessary for project operations.	piece	50	2	**$100.00**
15	Printing: hardcopies of the thesis document progress will be necessary during stakeholder presentations.	page	1500	0.1	**$150.00**
	F. OVERHEAD COSTS				
16	Legal fees	man hours	50	13	**$650.00**
17	Accounting fees	man hours	50	13	**$650.00**
18	Testing fees	man hours	50	13	**$650.00**
	G. CONTINGENCIES				
19	10% of the overall project costs.	N/A	N/A	N/A	**$2,531.00**
PROJECT TOTAL					**$27,841.00**

Table 8.3.1: Bill of Quantities

APPENDIX 4: TURNITIN

Appendix 4.1: TURNITIN Report

Turnitin Originality Report

Innovation of Acoustic Interior Design to Improve Video Call Quality for Home-based Millennials Telecommuting in Nairobi By Akello Odundo

	Similarity by Source
Similarity Index	
7%	Internet Sources: 5%
	Publications: 1%
	Student Papers: 4%

1% match (student papers from 24-Feb-2011)
Submitted to College of Technology London on 2011-02-24

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http://worthingtheatres.co.uk/

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https://www.statista.com/statistics/1122987/change-in-remote-work-trends-after-covid-in-usa/

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https://www.statista.com/statistics/1246368/communication-services-usage/

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https://arts-design.uonbi.ac.ke/sites/arts-design.uonbi.ac.ke/files/2021-06/BIOPHILIC%20DESIGN%20FUSED%20WITH%20ASIA%E2%80%99S%20UNIQUE%20NATURE%20FOR%20HEALTHY%20INTERIOR%20DESIGN%20SPACES%20AT%20PAWA254%2C%20NAIROBI..pdf

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OF BUILT ENVIRONMENT AND DESIGN
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https://repository.unai.edu/id/eprint/344/1/Full%20Paper%20Proceeding%209ISC%202022.pdf

< 1% match ()
Chachalika, Kassim Athuman. "A Comparative Analysis of Loan Repayments between Credit Cooperatives Societies and Microfinance Institutions Borrowers in Babati District", 2013

< 1% match (Frederick G Booth, Maurice Mulvenna, Raymond Bond, Kieran McGlade et al. "COVID-19 and lockdown: The highs and lows of general practitioner prescribing", 2021 IEEE EMBS International Conference on Biomedical and Health Informatics (BHI), 2021)
Frederick G Booth, Maurice Mulvenna, Raymond Bond, Kieran McGlade et al. "COVID-19 and lockdown: The highs and lows of general practitioner prescribing", 2021 IEEE EMBS International Conference on Biomedical and Health Informatics (BHI), 2021

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https://quieora.ink/keyword-ranking/1829572/explain+beats+audio

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Submitted to Telopea Park School on 2021-05-31

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https://hciss.newcastle.edu.au/lixinlei/desn2002/

< 1% match (Internet from 30-Apr-2023)
https://www.coursehero.com/file/p3gov56/approach-followed-in-this-research-is-qualitative-in-which-secondary-data-is/

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Submitted to University of Arizona on 2014-04-13

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< 1% match (Internet from 09-Apr-2023)
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http://repository.futminna.edu.ng:8080/xmlui/bitstream/handle/123456789/15102/Implications%20of%20Residential%20Housing%20Exposure%20to%20Urban%20Envtl.%20Noise%20online%20KUS%2b22-43_Proof.pdf?isAllowed=y&sequence=1

< 1% match (Internet from 20-Jul-2020)
https://springfield.edu/sites/default/files/inline-files/Final%20Copy%202019-2020%20Student%20Handbook%20%28WAttached%20CSWE%20Insert%29.pdf

< 1% match (Internet from 19-Mar-2023)
https://www.diva-portal.org/smash/get/diva2:1735422/FULLTEXT01.pdf

< 1% match (Internet from 26-Nov-2022)
https://www.iiste.org/Journals/index.php/RJFA/article/download/47571/49124

< 1% match (Internet from 18-Apr-2021)
http://www.ijocis.com/index.php/ijocis/issue/download/c10s1d/c10s1d

< 1% match (student papers from 25-Sep-2018)
Submitted to Signal Mountain Middle High School on 2018-09-25

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Appendix 4.2 TURNITIN Receipt

turnitin

Digital Receipt

This receipt acknowledges that Turnitin received your paper. Below you will find the receipt information regarding your submission.

The first page of your submissions is displayed below.

Submission author:	Akello Odundo
Assignment title:	Postgraduate Thesis Project
Submission title:	Innovation of Acoustic Interior Design to Improve Video Call ...
File name:	Akello_BDS_604_Thesis.docx
File size:	9.53M
Page count:	76
Word count:	11,711
Character count:	71,264
Submission date:	01-Jun-2023 09:18PM (UTC+0300)
Submission ID:	2106894979