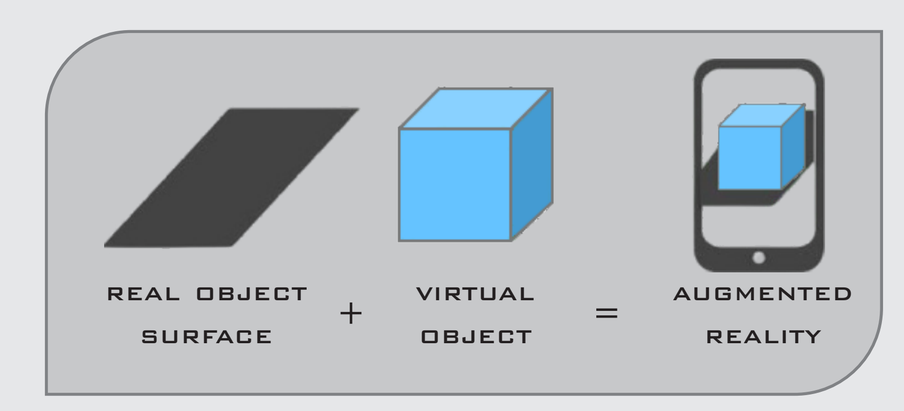
Augmented Reality in Deconstruction: Assessing the Potential for Advancing Circular Methods

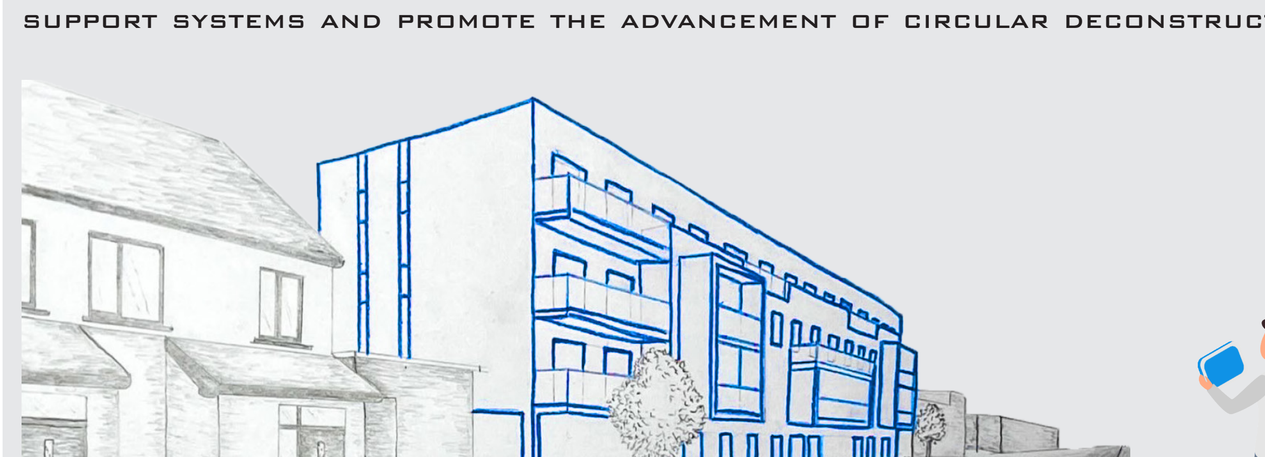
1. Introduction:

Augmented Reality - A technology that overlays a computer generated model onto a user's view of the real world, resulting in a combined view.



Selective Deconstruction - The dismantling of building installations and structures while preserving and sorting their component parts, favouring the reuse and quality recovery of building materials.

The ability of Augmented Reality to enable users to visualize construction elements and their associated data while on an end-of-life building site could facilitate decision support systems and promote the advancement of circular deconstruction methods.



2. Research Aims

My aim is to investigate the potential of Augmented Reality technology to be utilized as a tool to support sustainable deconstruction practices.

Specifically, the research aims to identify the ways in which AR can be used to visualise hidden building elements, display their environmental data and aid in implementing a waste management plan during the end-of-life building stage.

4. Objectives

1. To conduct an extensive literature review into AR as a construction tool, the upward trajectory of BIM-LCA and how these advancements could be linked with improving circular deconstruction.

2. To develop a physical prototype that displays the potential of AR technology to visualise BIM models at a 1:1 scale.

3. To create an end-of-life building case study scenario that demonstrates how LCA data can be incorporated into a waste management plan and utilizes AR on-site to enhance deconstruction methods.

4. To produce a video recording showcasing the implementation of AR technology in the context of circular dismantling.

5. To evaluate the effectiveness of using AR and LCA data during the end of-life stage of a building, and to identify any barriers or limitations to the widespread adoption of this technology in the AEC industry.

Circular Deconstruction

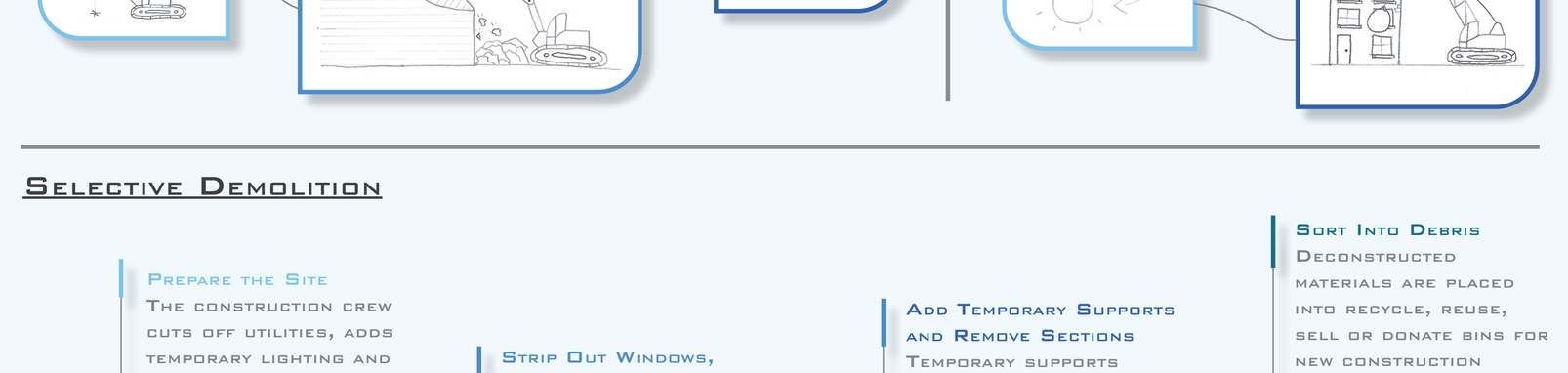
Circular deconstruction can be defined as a well-considered selective dismantlement of building components in prevision of a future reuse, repurposing or recycling. To select the most environmentally friendly deconstruction approach (waste management strategy), an evaluation of multiple contributing factors is necessary. Understanding of the building materials, site conditions, recycling process, price of disassembling energy use and energy cost are some of the contributing factors.

Building Demolition Methods:

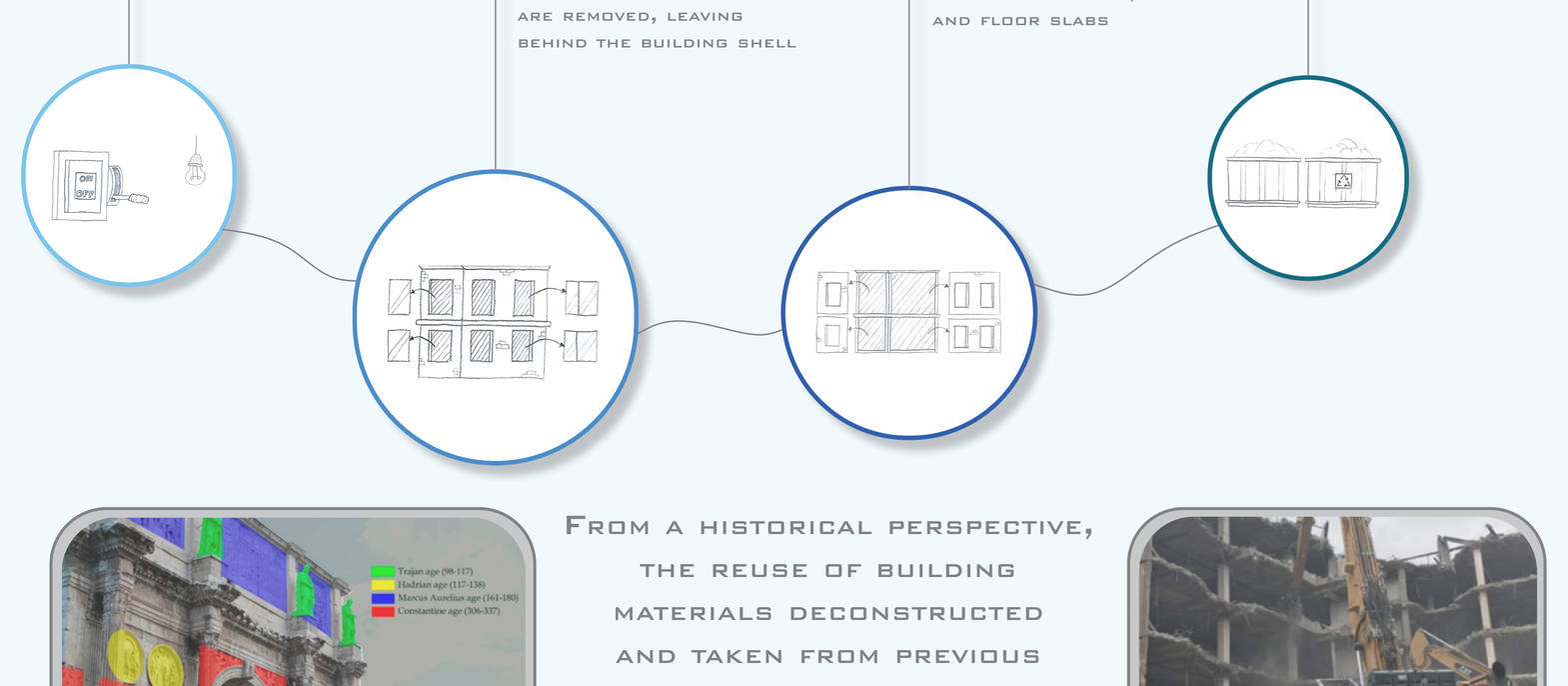
Building Implosion

Excavator Demolition

Wrecking Ball Demolition



Selective Demolition

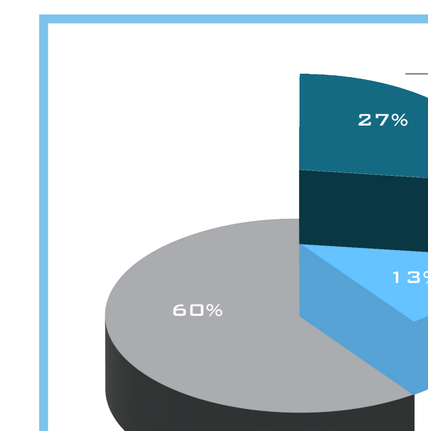


The Reliefs of the Arch of Constantine

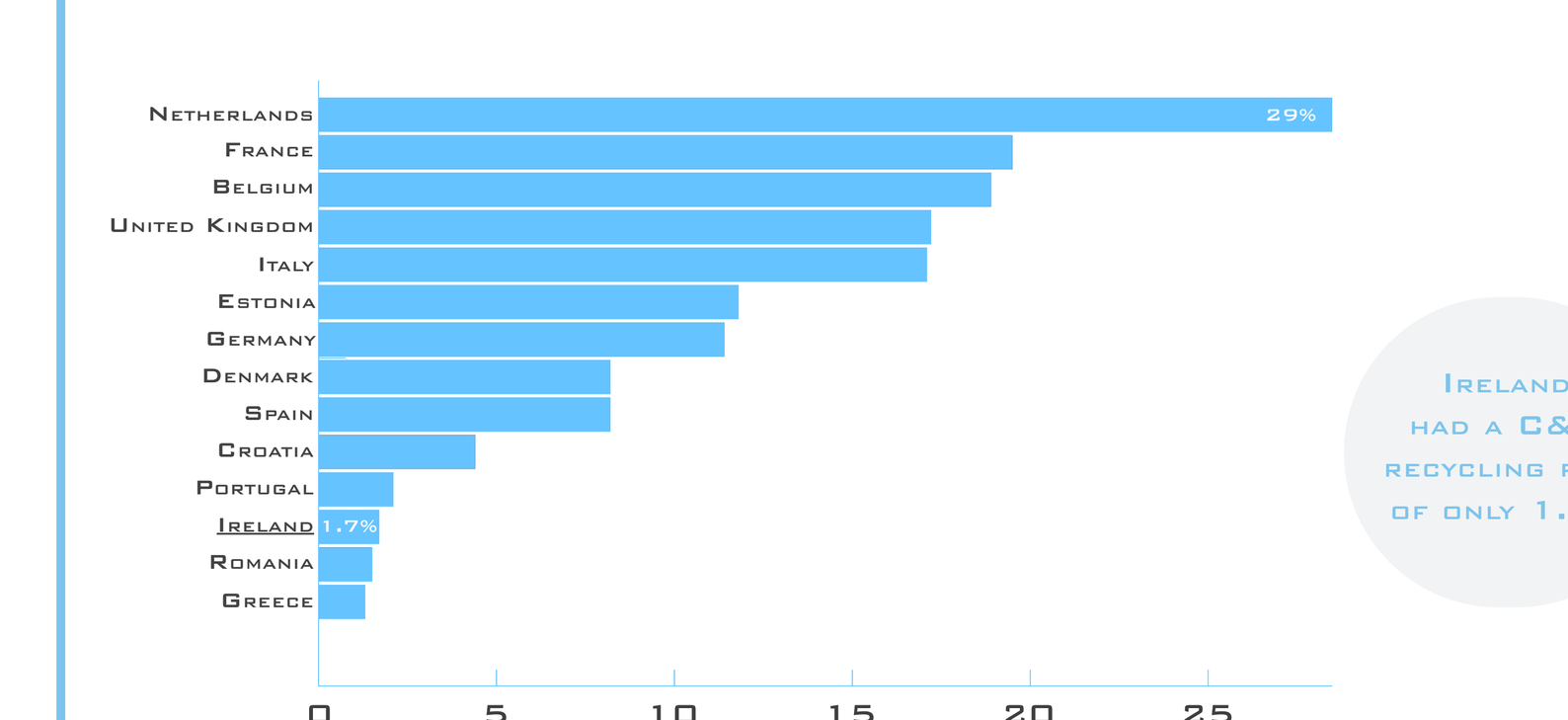
From a historical perspective, the reuse of building materials deconstructed and taken from previous constructions is quite common throughout the history of human life. The triumphal Arch of Constantine, situated in Rome and constructed in approximately 315 AD serves as an example. Some of the elements used to construct the arch were taken from previous monuments dedicated to emperors Trajan, Hadrian and Marcus Aurelius.

Demolition of Oisin House

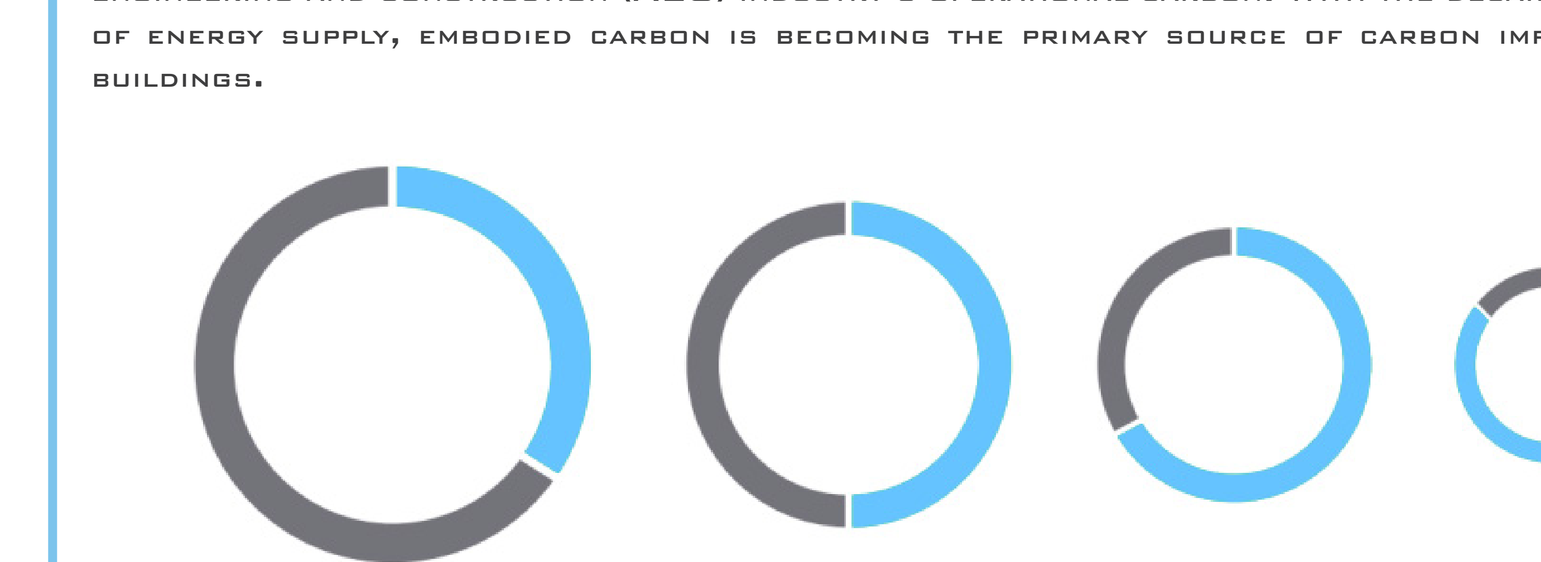
3. Motivation



The construction industry is a major contributor to global greenhouse gas emissions, the built environment generates 40% of annual global CO2 emissions with a significant portion of these emissions (13%) coming from the materials used in building and infrastructure projects.
Source: International Energy Agency (2022)

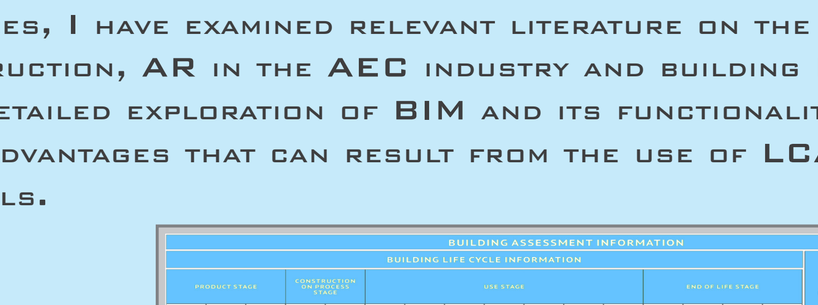


The accumulation of carbon in our building is shifting over time. Lowering costs of renewable energy solutions due to policy decisions have already started to reduce the architecture, engineering and construction (AEC) industry's operational carbon. With the decarbonization of energy supply, embodied carbon is becoming the primary source of carbon impacts from buildings.



5. Literature Review

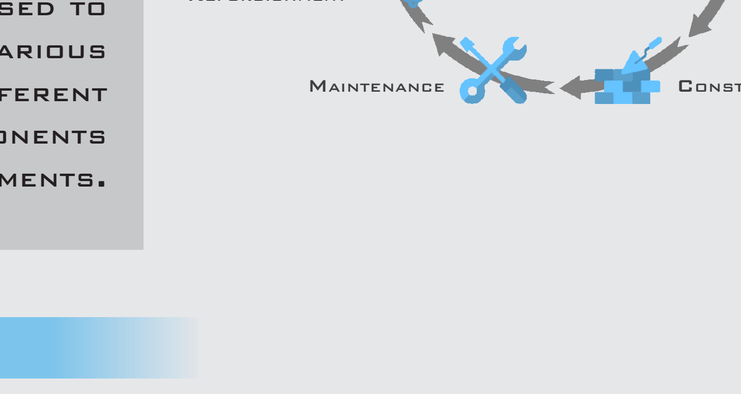
To achieve the overall aim of investigating the potential of AR to promote sustainable demolition practices, I have examined relevant literature on the current applications of circular deconstruction, AR in the AEC industry and building LCA methods. This section also provides a detailed exploration of BIM and its functionalities, along with an analysis of the potential advantages that can result from the use of LCA software incorporated into precise BIM models.



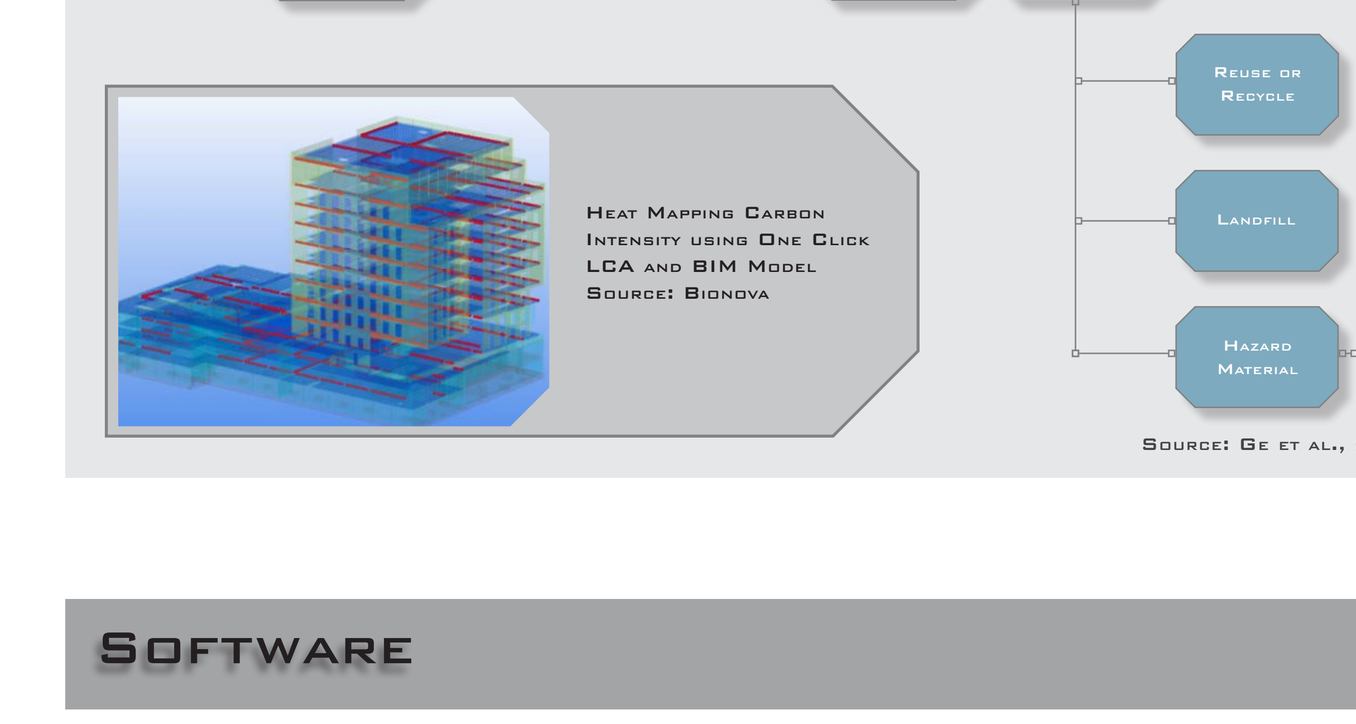
BIM and LCA

One method to obtain a more detailed material and quantity take-off during the development of a waste management plan is the use of BIM software with LCA plugins.

Databases and environmental product declarations (EPDs) are used to offer information on the various environmental effects of different construction materials, components or elements.



Waste Management with BIM



Source: Ge et al., (2017)

Software

The software employed for this research can be categorized into three subheadings:

Autodesk Revit is used in this study for digital prototype development and for it's integration of LCA and AR software.

Tally is an LCA software tool employed to compute the environmental impacts of designs and has a direct Revit plugin.

Unity Reflect is an AR software that integrates with Revit, allowing for the importation of any BIM data embedded within a project.

Augmented Reality in Construction

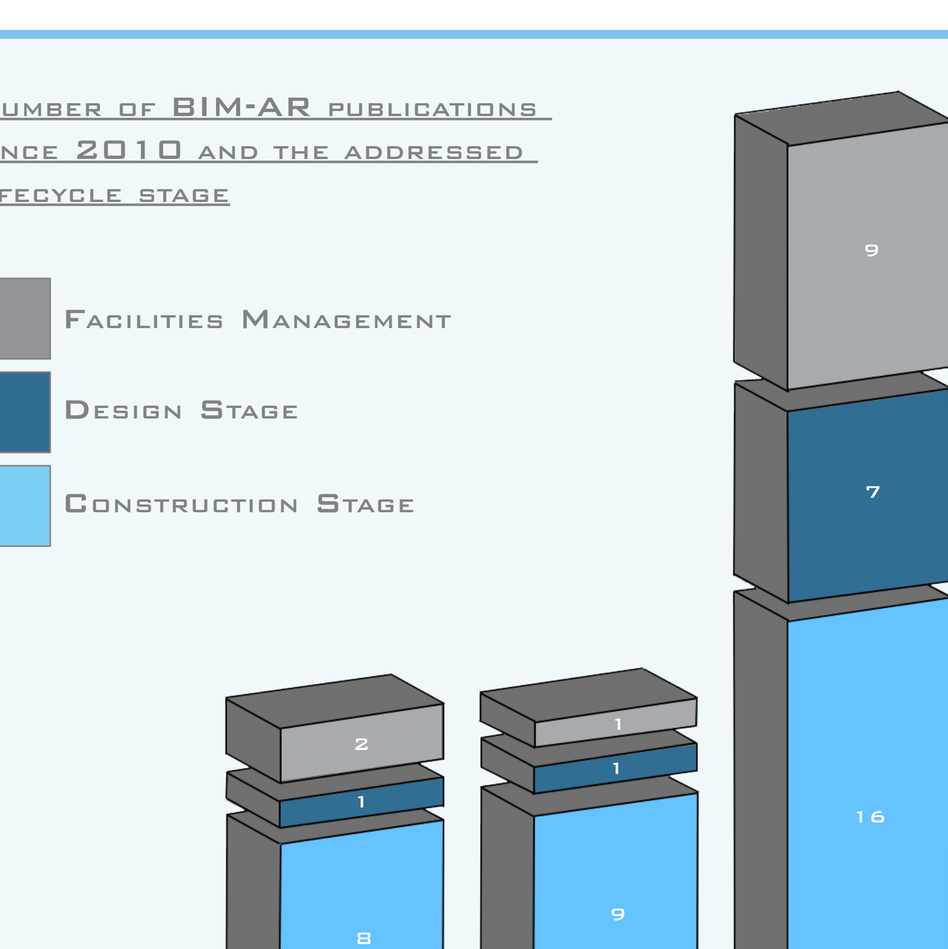
Augmented reality allows a team to collectively experience BIM data interwoven with the built environment.

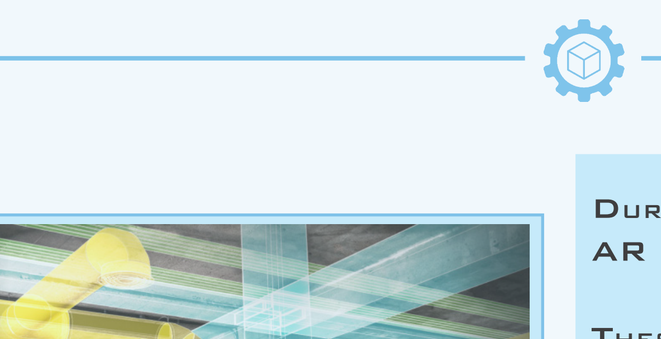
This technology is being adopted by designers, engineers and builders opening up far-reaching opportunities for the construction industry.

Amin et al., (2023) completed a study using 55 published articles on the topic of BIM-based AR platforms since 2010. The study indicated that research into the topic of AR and BIM as a tool for the construction stage is the most common.

Applications in the design stage and during facilities management are becoming more popular as a research trend.

However, there is a lack of publications released on the potential of AR as a tool during the deconstruction stage of our buildings.





Source: XYZReality, 2022

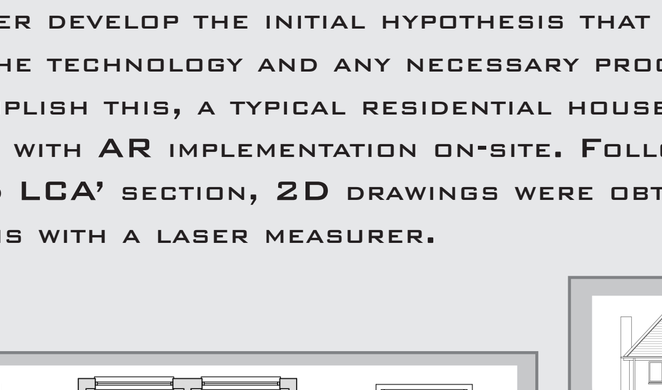
During the desktop research for this study, several companies offering AR construction solutions were discovered.

These companies assert that their products can eliminate rework, enhance quality control and provide up to nine times return of investment when used.

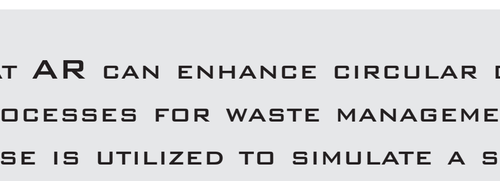
A study on the use of AR as a deconstruction tool could provide insights into the effectiveness and efficiency of using AR for deconstruction purposes as well as any potential challenges or limitations that may arise.

7. Case Study

To further develop the initial hypothesis that AR can enhance circular deconstruction, a case study that applies the technology and any necessary processes for waste management planning is required. To accomplish this, a typical residential house is utilized to simulate a sustainable deconstruction approach with AR implementation on-site. Following the waste management process outlined in the 'BIM and LCA' section, 2D drawings were obtained by accurately measuring the existing conditions with a laser measurer.



Existing Ground Floor Plan

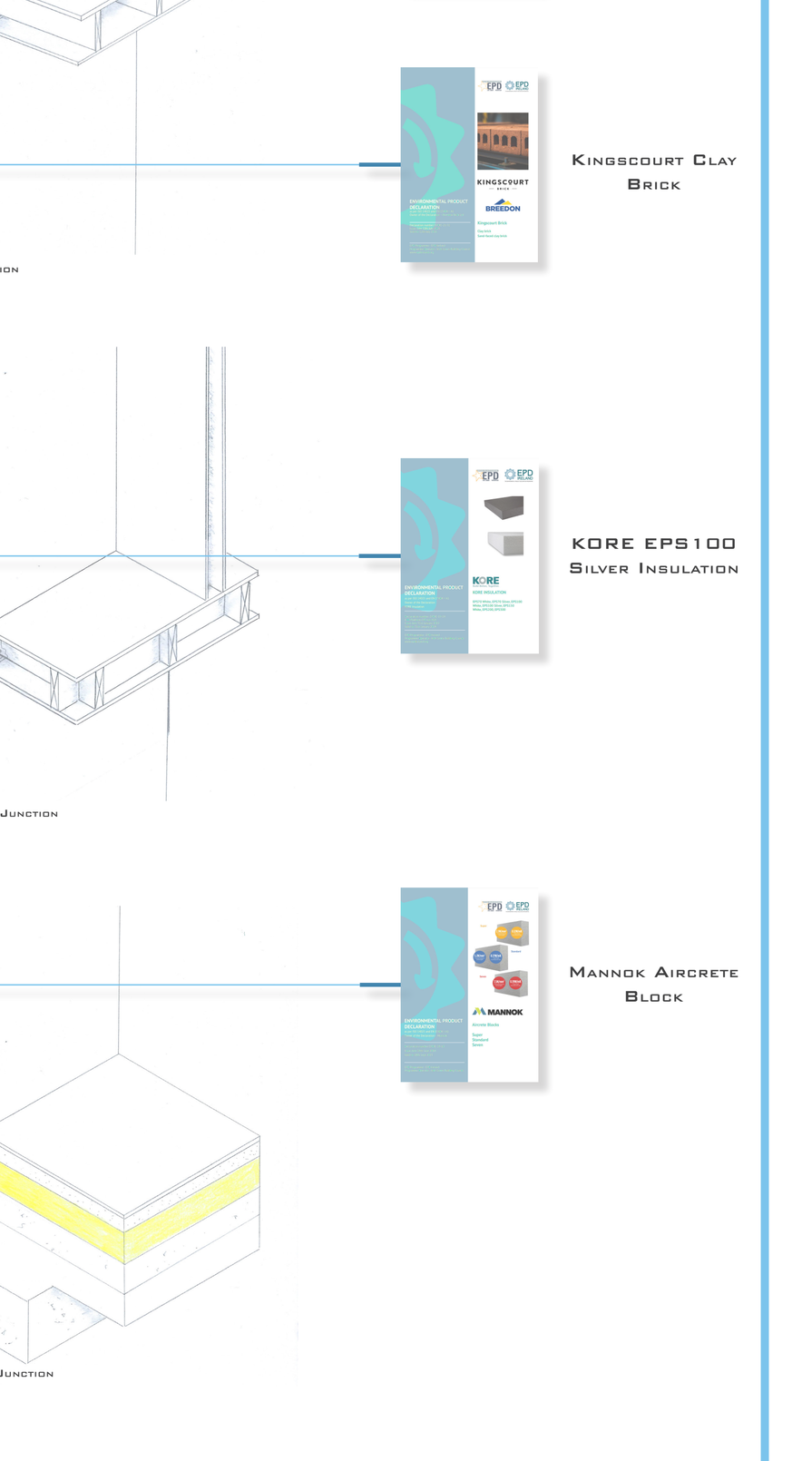


Existing Rear Elevation

Subsequently, a 3D BIM model was created to facilitate material take-off calculation as well as LCA and AR software integration. Based on previous architectural drawings, the building's key junction build ups were identified to enable precise modelling of concealed structural elements.

Key Junctions

Through the use of LCA software, EPD data can be assigned to the dwelling's construction material make-up.

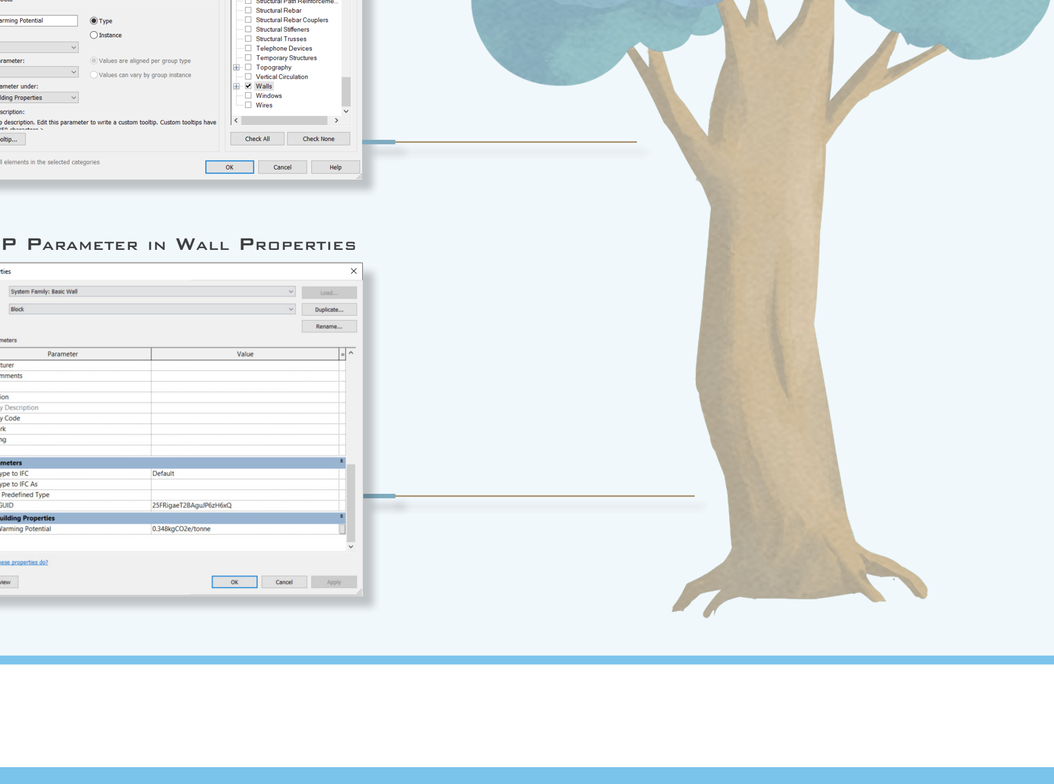


EPD IRELAND

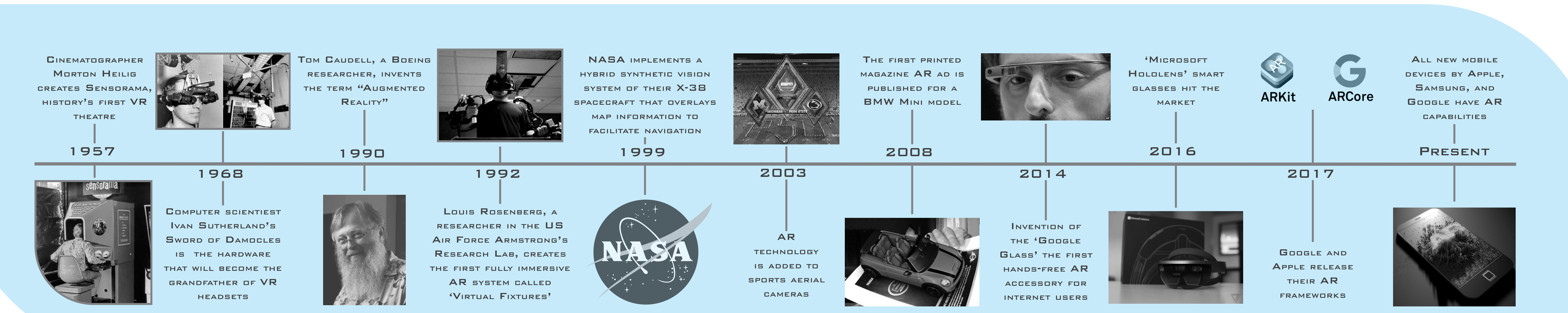
The Irish Green Building Council has established the EPD Ireland programme to allow Irish construction product manufacturers to develop and publish Environmental Product Declarations for their products. This provides specifiers with clear transparent information on the impact of the products which can be used in building level Life Cycle Assessment or embodied carbon calculations.

LCA Data

The BIM model was then transferred to 'Tally' in order to produce material take-offs and identify main waste streams. After generating the LCA for the demolition of the dwelling, the end-of-life environmental impact data was linked to the BIM model using shared parameters.

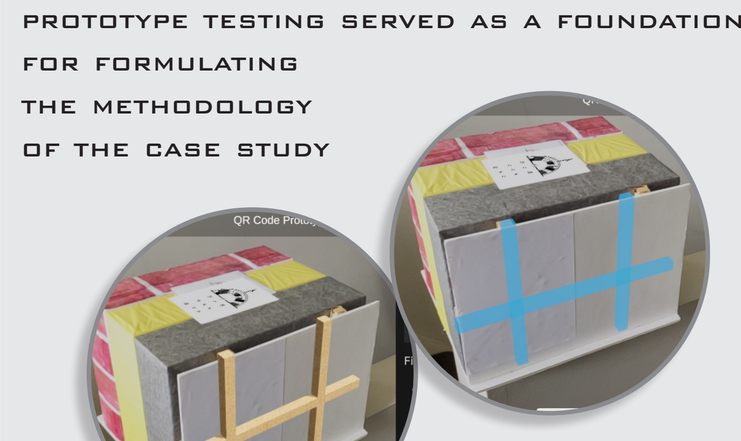


History of Augmented Reality:



Physical Prototype Findings

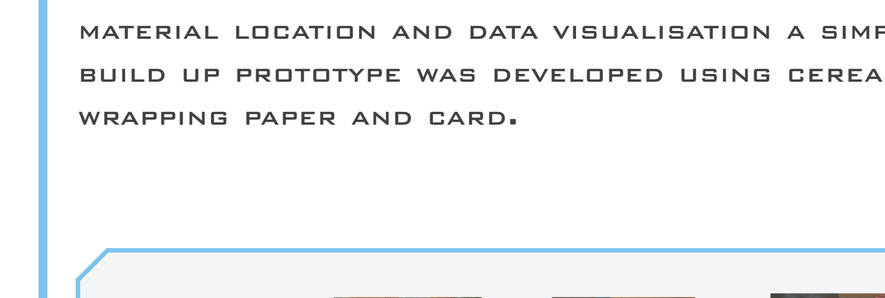
The positive outcomes of the physical prototype testing served as a foundation for formulating the methodology of the case study



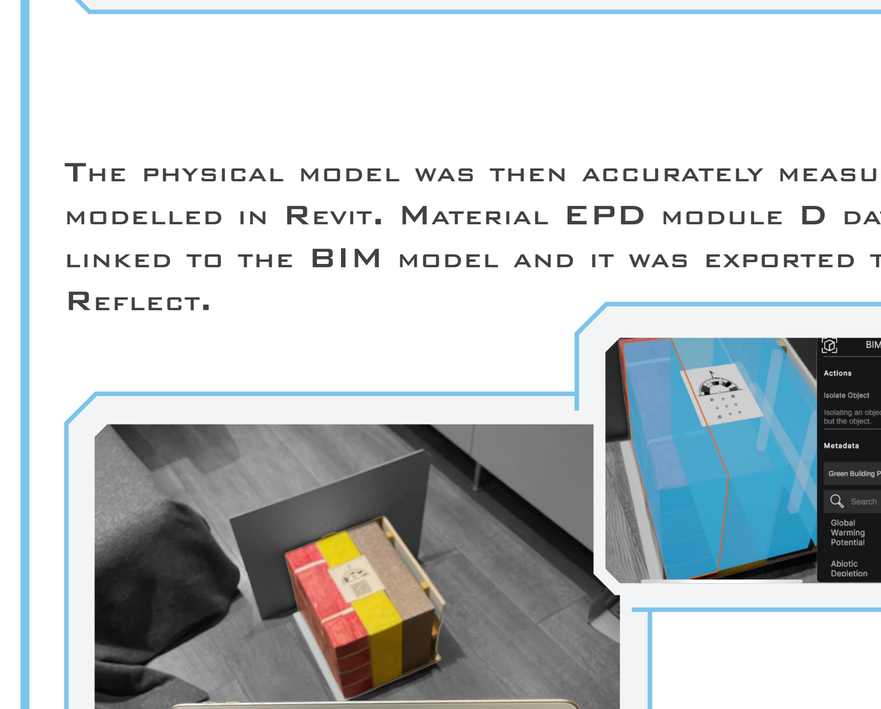
During the creation of the prototype, knowledge of the functionalities of AR software and their direct connections to Revit was acquired

6. Physical Prototype

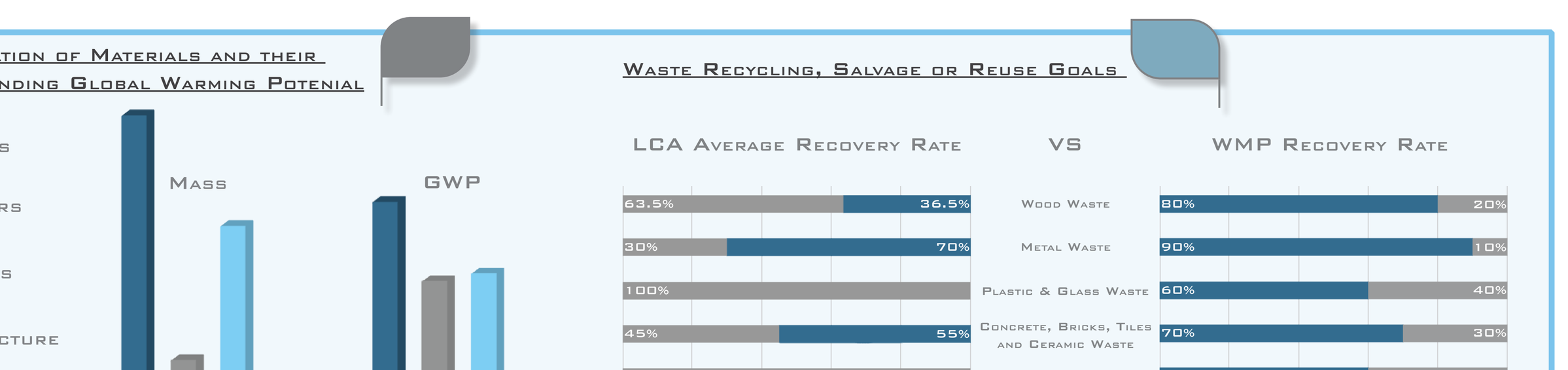
To create a model that displays the capabilities of AR technology in terms of accurate surface anchoring, material location and data visualisation a simple wall build up prototype was developed using cereal boxes, wrapping paper and card.



The physical model was then accurately measured and modelled in Revit. Material EPD module D data was linked to the BIM model and it was exported to Unity Reflect.



Waste Management Plan



Instructions for Separating and Collecting Waste

Proper separation and collection of materials at the job site is vital for maximising salvageable materials and minimising waste. List of waste (LoW) codes were identified for the main waste streams of the case study and assigned to their relevant BIM families.

Specific separation requirements such as keeping ferrous and non-ferrous metals separate were identified in the WMP document.

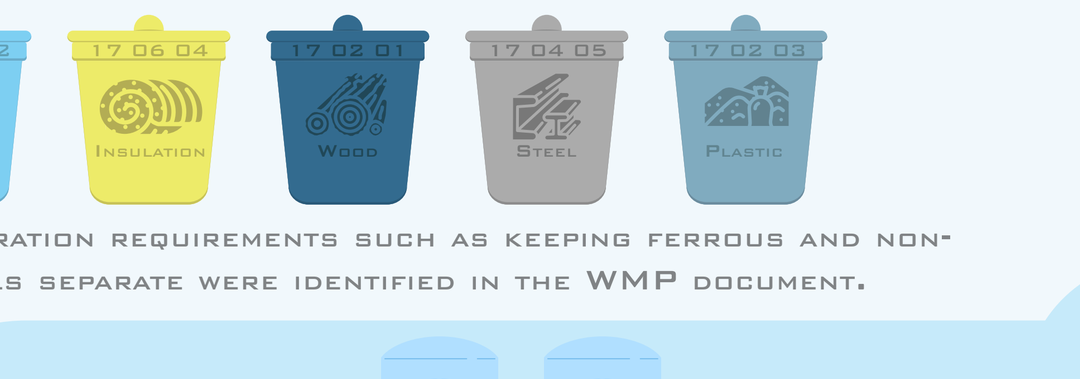
Intended Procedures for Handling Waste

Safety measures and intended procedures for handling different wastes during deconstruction is crucial to a good WMP.

These procedures were outlined in depth in the WMP document and then assigned to relevant materials in the BIM modelhe safety data was then implemented on site in AR.

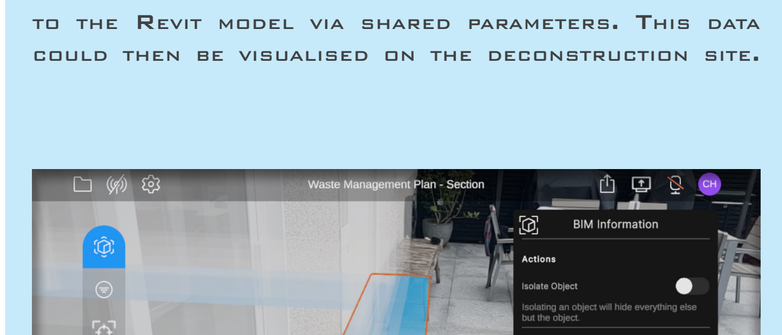
Method of Disposal

The National Waste Collection Permit Office (NWCPO) have a database of permitted waste collectors in Ireland that can be filtered by LoW Code and County. Using this, waste materials were filtered into their LoW Code waste bins and could then be collected by local waste collectors that deal with that specific material.

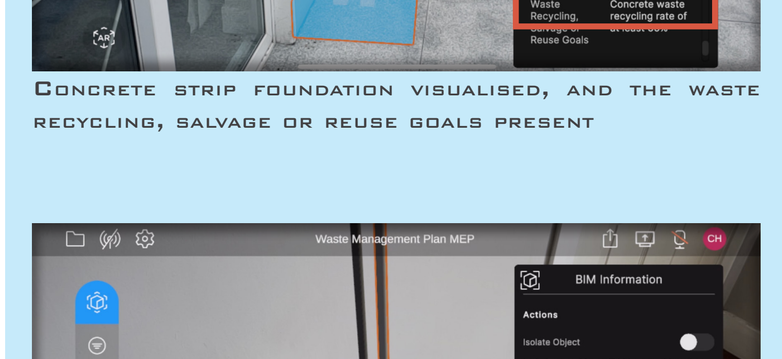


AR a Tool for Deconstruction

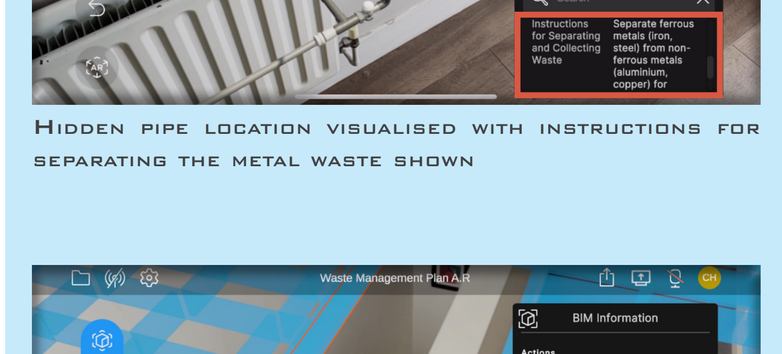
Main guideline points from the WMP were then linked to the Revit model via shared parameters. This data could then be visualised on the deconstruction site.



Concrete strip foundation visualised, and the waste recycling, salvage or reuse goals present

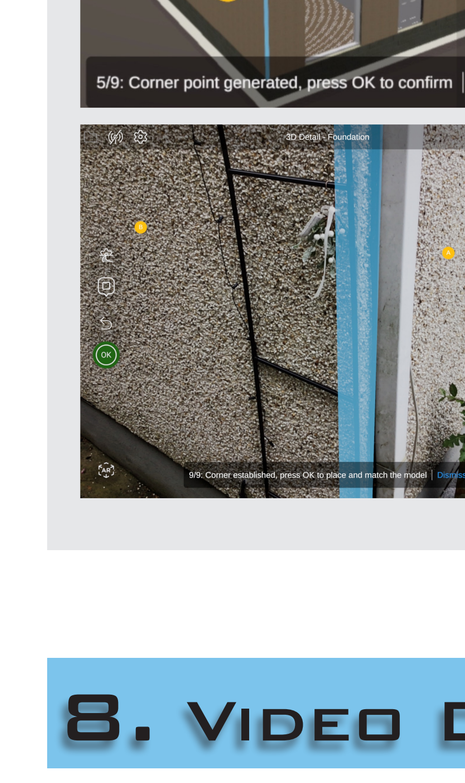


Hidden pipe location visualised with instructions for separating the metal waste shown



First floor joist layout around stairs visualised with specific health and safety requirements for handling the timber waste highlighted

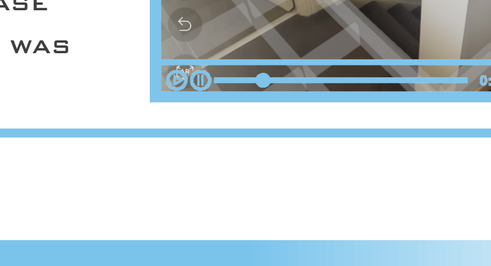
AR On Site Implementation



To implement the waste management plan on-site using AR a corner alignment technique was preferred over the QR scanning method seen in the physical prototype. This was due to the increase in imprecision with distance from the QR scanning point. The corner alignment method can be repeatedly used on any corner within the dwelling to achieve room-based accuracy and to realign the model.

8. Video Documentation

Early AR testing revealed that capturing single frames of AR-use did not effectively convey the adaptibility to movement of the BIM projections. A one minute demonstration of video of the physical prototype and case study AR use was created.



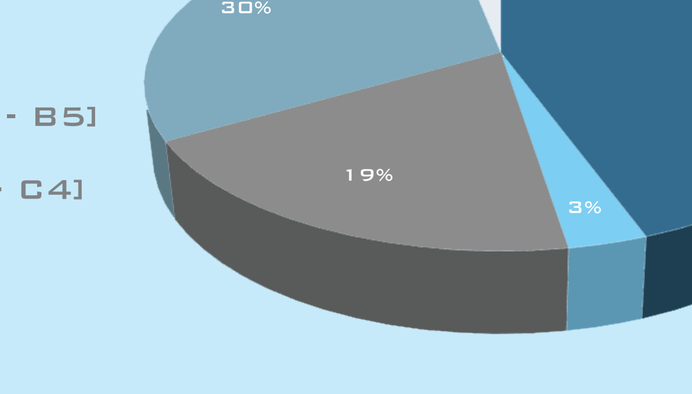
9. Results & Analysis

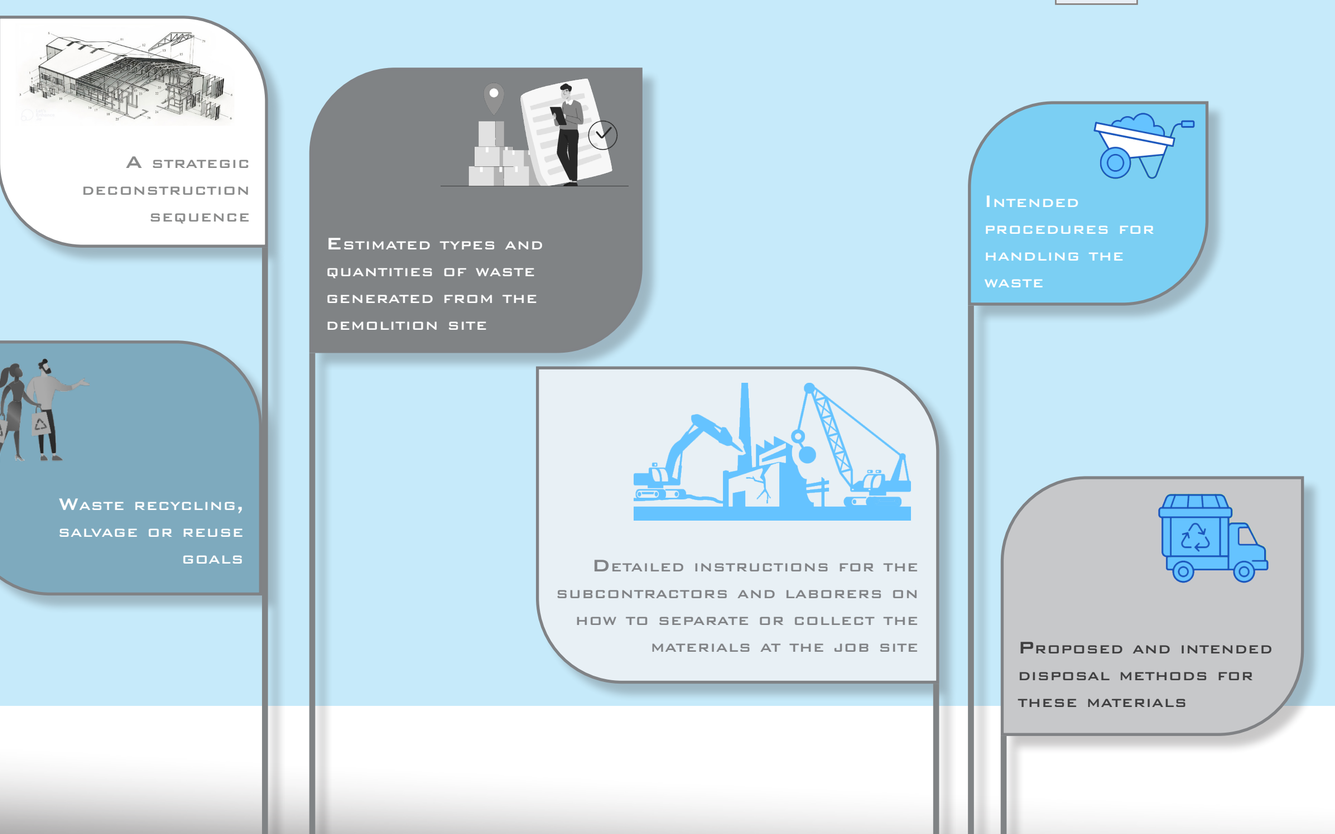
LCA Key Findings:

Following the creation of a 3D BIM model of the existing dwelling, an LCA calculation for the building was achieved.

From this, the study identified main waste streams and their corresponding environmental impacts.

It was found that the end-of-life accounted for 30% of the building's cradle to gate GWP.





EPA Guidelines for developing a WMP

Following the guidelines set out by the EPA on completing a WMP for a demolition project in Ireland, a site specific WMP was developed for the case study dwelling.

The use of LCA software integrated with BIM was key to hitting each guideline heading throughout the document.

Each guideline is covered in detail throughout the WMP document, however some of the key findings are highlighted in the WMP section.

Deconstruction Sequence

Top Down Deconstruction:

- Phase 1: Utilities Disconnection
- Phase 2: Furniture Removal
- Phase 3: Door Removal
- Phase 4: Hazardous Material Removal
- Phase 5: Roof Removal
- Phase 6: Attic Structure Removal
- Phase 7: FF Window Removal
- Phase 8: FF Internal Walls and MEP Removal
- Phase 9: FF External Walls Removal
- Phase 10: FF Build Up Removal
- Phase 11: GF Window Removal
- Phase 12: GF Internal Walls and MEP Removal
- Phase 13: GF External Walls Removal
- Phase 14: GF Build Up and Slab Removal
- Phase 15: Rising Wall aand Foundation Removal

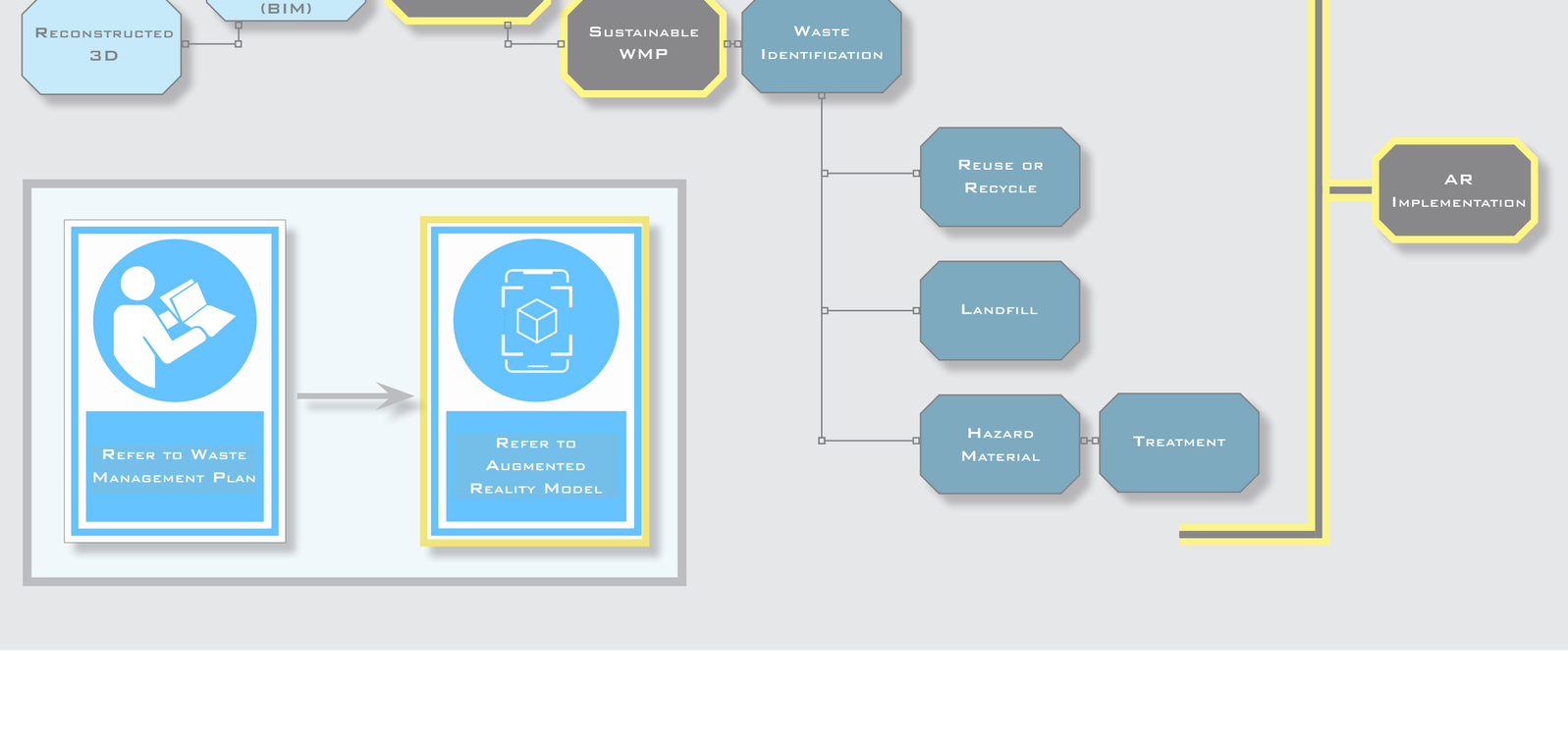
10. Conclusions

From the creation of a physical prototype, knowledges of the functions of AR software such as it's ability to visualise hidden building elements, it's data importation and it's direct connections to Revit were acquired and these findings were essential to the creation of the case study

Through a case study, it was found that LCA data can be utilized to create an in-depth waste management plan with emphasis on sustainability and that AR can be used to implement this on site

A two minute video presentation was created following the case study and showing the potential of using AR during the deconstruction phase

A new workflow was created implementing LCA and AR into an existing method for producing a WMP from a BIM model and the results from using this methodology is promising



Future Research & Discussion

If something is modelled accurately with BIM data embedded, AR can represent it's physical form while also displaying any information. What other industry could this effect?

After waste is collected, the best practices for waste collection facilities was outsite of the scope of research but is a very important factor, the European Waste Hierarchy should be followed.

Neural radiance fields (NeRFs) are a technique that generates 3D representations of an object or scene from 2D images by using AI. These NeRFs can be created using mobile devices and brought into AR.

Limitations

There is a level of estimation involved in the LCA calculation of Modules C and D

It can cost more to deconstruct sustainably. The demolition of the case study was only in theory, a study comparing costs of AR deconstruction with standard methods is the next step.

Current scanning ability varies with devices and surface textures

TU Dublin — Ollscoil Teicneolaíochta Bhaile Átha Cliath — Technological University Dublin
Cal Henderson
C19339371