

**School of Built Environment  
Department of Architecture and Interior Architecture**

**Rematerial-Oriented Design:  
A Framework for Architectural Upcycling**

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**This thesis is presented for the Degree of  
Doctor of Philosophy  
of  
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# Declaration

To the best of my knowledge and belief, this thesis contains no material previously published by any other person except where due acknowledgement has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

**Human Ethics.** The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (EC00262), Approval Number #RDHU-09-16.

Signature: 

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# Abstract

Upcycling is the practice of recycling, reusing or repurposing materials to a condition with improved value. Architects and designers intuitively follow this practice to seize opportunities to reposition existing or discarded objects, elements or structures in a new context. Despite the relevancy of and current interest in architectural upcycling, research on the topic is still limited and incipient, preventing improvements in the practice. However, design through the process of upcycling often results in project abandonment, failure or poor outcomes because there is insufficient formal understanding of the upcycling process. Successful incorporation of salvaged or reclaimed materials in architecture requires an approach that differs from traditional design. This thesis addresses the process of architectural upcycling and introduces a *rematerial-oriented design* (ROD) framework to approach the phenomena of design through upcycling.

The study develops an original framework for ROD and a supporting model for a more conscious, effective and efficient process for architectural upcycling. The formalisation of the structure of ROD is accomplished through the investigation of three relevant dimensions during ROD related to design process, design knowledge and materiality. The interface between the three is termed *rematerial interaction*. In conjunction with the theoretical background, the thesis presents empirical studies of rematerial interactions performed by novice, experienced and expert designers. This evidence is used to gain an understanding of the factors related to designers' variables, material constants and design decisions that must be considered in the ROD process. Furthermore, a reference model representing the current situation guided the construction of the ROD framework. The reference model showed that in traditional design practices, crucial information about awareness, effectiveness and efficiency of ROD is overlooked, lost or disconnected.

The findings of the thesis motivated the building of an impact model termed *conscious rematerial interaction* and represents the desired process improvements for ROD. Finally, the thesis proposes an information management instrument for *rematerial information modelling* (REMIM) to provide practical aid to designers at the convergence moments of the ROD process. REMIM is intended to direct design decisions; organise and connect information in current projects; or update, structure, store and make accessible material information for reuse in future ROD projects. The knowledge gained during this study provides a theoretical base for further research into ROD and establishes opportunities for advances towards the development of computer-based REMIM to enable *conscious rematerial interaction* in formal design scenarios.



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# Foreword

I developed my first insights into the present research questions more than a decade ago when I studied architecture during an undergraduate course. At the time, I believed it was undemanding to create good designs using new materials that matched the precise specifications of the project and were selected to meet certain requirements and expectations. To me, this plan was simple: choose and buy sparkling new goods. If something did not work properly or was outdated, one could just buy new material. In my opinion, this approach made the problem-solving process dull. For me, the exciting task was to create a sound, striking design using whatever was available. Even as a novice designer, I believed it was wasteful to acquire new material when there were plenty of easily accessible supplies that could be reused.

Upcycling has always been part of my everyday life, whether I am using trivial or meaningful goods. Countless times, I have looked at a trash bin or the objects in my hands and wondered about the possibility of using them again. I must admit, however, that what motivated me was not a real concern for the environment or sustainability but rather the inherent personal challenge these ideas posed, as well as the belief that nothing had to be the same thing forever. That initial thrill grew to real joy and excitement when I could devise means for extending that material's usefulness. I felt proud of having thought of something that was different and outside the box or presented a money-saving solution. My plans worked at times, failed at others and were occasionally forgotten.

I revisited the topic more seriously while completing my master's degree, and my tendency towards nonconformity directed my research into the viability of applying a resource profusely available in some regions of Brazil. In this study, I recommended using aquatic macrophytes (which are highly populous in backwaters) as a base for adobe bricks and as a posterior construction material.

That study showed that in the context of northern Brazil, most conditions were favourable for the adoption of this technology; however, the existing barriers were sufficient to prevent the widespread use of non-standard materials in. Those fundamental obstacles appeared at both the bottom and top of the supply chain among users and builders alike (Pereira, 2008).

Instead of losing hope, I reflected on both the delicacy of the topic and the bias. Architecture with alternative materials is possible and has long been under development,

but these techniques are not right for every user, designer, maker or builder. Furthermore, the chances of successfully implementing alternative materials are better when the agents involved share similar ideologies.

After assimilating these ideas, I understood that the practice would not be adopted by the majority of the professionals in the field for the next few decades because resources for the manufacture of new products from raw material remain abundant. However, reflection on and support for the practice of using alternative materials will not only enhance the experience for those who already implement the practice, but also encourage the crescent body of designers interested in architectural upcycling.

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# List of Abbreviations

BIM	Building information modelling
CAD	Computer-aided design
CAM	Computer-aided manufacturing
CBD	Case-based design
CLMC	Closed-loop material cycle
DIY	Do it yourself
DRM	Design research methodology
DS	Descriptive study
GOD	Goal-oriented design
MOD	Means-oriented design
PBD	Precedents-based design
PS	Prescriptive study
RC	Research clarification
REMIM	Rematerial information modelling
ROD	Rematerial-oriented design

**PART I**  
**Research Clarification**

# PART I – Research Clarification

*“Trash is the failure of imagination.”* (Kramer, 2012)

Part I identifies the research problem, the assumptions underlying the study and the requirements for addressing the research hypothesis. It is divided into three chapters, as follows:

Chapter 1 introduces the thesis, formulates the research questions and hypothesis, and addresses the objectives and significance of the study. This section delineates rematerial-oriented design (ROD) as being a challenging, but potentially improvable design activity through appropriate formalisation.

Chapter 2 addresses the main dimensions of ROD, namely the design process, material and designer. Particularly, this chapter presents an overview of the existing research into design, architectural materiality and upcycling. In conjunction with the literature review, the section presents a framework for ROD. It also discusses the data collection and analysis that occurred the investigation regarding the evolution of concepts and developing ideas.

Chapter 3 details the current study’s research methodology to address the hypothesis using the theoretical background and three projects linked to practice. The sections introduce the specific objectives, participants, materials and procedures applied to minor, complementary studies of different design rematerial interactions. The chapter looks at designers’ processes of thinking, designing and creating within the stages of discovery, definition, development and delivery in ROD.

# Chapter 1 Introduction

## 1.1 Research Context

Materials produced from precious resources are often rejected prematurely because of changes in circumstances or fashion, damage or being deemed inappropriate. Before the second half of the 20th century, most people could not afford to replace goods so casually, but contemporary users seem incapable of sustaining long-lasting relationships with goods (Chapman, 2005; Strasser, 1999)

This problem of materiality has given rise to a growing body of research that has addressed aspects of reuse and recycling in the architecture, design and construction sectors. Common foci are designing for deconstruction, demolition management, adaptive reuse and construction with reclaimed materials. It is also common to find studies on the development of more resilient and durable designs.

In the industry, certain designers and architects consider discarded materials a valuable resource and are exploring a reverse process for conceiving architecture. In this approach, the recognition of available material is the starting point for problem-solving in design and is followed by the establishment of a method for detailing. This practice resituates rejected materials within a new context and integrates meaningful materiality into design.

Apart from investigations that reflect predominantly on case studies, general agents involved in the process and their roles in managing materials, however, there is lack of assessments on the processes and decisions of designers in regard to the use of reclaimed material in architecture. For this reason, the activity is often compared with craft or bricolage, and the designer is required to have a way with, demanding additional time, effort, inventiveness and spatial visualisation capabilities. Additionally, most designers undertake the process randomly and without an established understanding of the practice, which increases the risk of plan abandonment, failure or poor outcomes.

The term *rematerial* was introduced by Bahamón and Sanjinés (2010) in the book *Rematerial: From waste to Architecture*. This word refers to material that has the potential to be reclaimed and used in a new and improved situation. Rematerial-oriented design (ROD), formalises a longstanding practice and alludes to the design process driven by architectural upcycling or material recontextualization for during architectural design.

More specifically, ROD is the architectural recontextualization of previously used materials, elements or structures, comprises design approaches focused on materiality to make particular projects both unique and audacious *and* intended to touch the imaginary and address the realm of material thinking in the early stages of architectural design. ROD involves the designer and the maker, as well as craftsmanship, is conceived as a sustainable practice that contributes to reduce the generation of waste and minimise the disposal of potentially suitable architectural materials. Rematerial-Oriented Design is therefore not uncommon in the traditional design process but is usually performed intuitively.

In conventional design, problem-solving involves the development of concepts until they are meaningful and detailed enough to be represented, read, understood and translated into physical structures. A significant part of understanding the design problem is establishing its constraints. The proposal proceeds from preference but is shaped by the restrictions and modulated by context and circumstance (Gross & Fleisher, 1984).

However, the main distinction of ROD is that material becomes the central driver to design rather than being an object for later selection and specification. The process also relies on the designer's skills, preferences, context and circumstances, but the constraints of remateriality change the positions and perspectives of the usual design problems. Concomitantly, material response to an interaction will depend on the process adopted and the information flow – in other words, the designer's knowledge and attitude.

From the designer's perspective, context and circumstance are abstractions that may be known but are not manipulable. Design process selection and material information management, however, are under their control. Based on this context, the thesis explores three main dimensions related to the architect's scope in ROD: design process, design knowledge and materiality. In this investigation, the interface between the three dimensions during of ROD is termed *rematerial interaction*.

The theoretical background for these design spheres establishes the conceptual framework for ROD and delineates the scope of empirical data collection via practice-based rematerial interactions. Thus, this thesis investigates ROD performed by novice, experienced and expert designers with an emphasis on identifying the tangible factors behind that unconscious approach to design. A model for process improvement is deployed posteriori followed by insights directed to the development of a practical supporting tool.

To accomplish these aims, the research methodology was divided into three main stages, split into three parts: research clarification (RC), the descriptive study (DS) and the prescriptive study (PS). RC contains indications to support assumptions related to the research goal and was continuously updated to adjust the theoretical framework in accordance with the findings. The DS was carried out to obtain a better understanding of the existing problem, and the PS was developed to support and address relevant factors. The three stages are described in detail in Chapter 3 in the section on methods, which follows the research background.

## 1.2 Problem Statement

Considerations for repositioning discarded materials are unusual in the traditional architectural design process. Furthermore, a review of the literature established that there is no current supporting framework for such a design approach. In practice, evidence suggests that ROD being performed unconsciously and intuitively without supporting tools or an established formal process. This condition raises uncertainties and increases the occurrence of redesign during the process. Furthermore, this unconscious approach lessens productive experimentation. The risks of poor results or project rejection, abandonment or failure are elevated. Moreover, the lack of consolidated procedures and explicit language limits professional interactions and practical sharing of ROD experimentation.

In research, the non-existence of formal approaches prevents the development of ROD knowledge structures, methods and exploration of relevant criteria. Additionally, imprecise terminology restrains communication and makes the collation of related research topics difficult. In both practice and research, therefore, these issues hinder progress towards process comprehension and improvement, preserving ROD's character as a craft or random, intuitive and spontaneous activity.

Attentiveness to the formalisation of the processes and materials used in ROD process is expected to maximise existing means, empower the monitoring and adaptation of architectural upcycling activities, and improve the accessibility of information, methods and tools. In early stages of design, appropriate guidance in establishing constraints and accessing the right information can raise the chances of successful outcomes with minor influence on designers' creative freedom.

## 1.3 Research Questions

In light of the problems discussed above, the central research question addressed in this thesis is as follows:

*What factors associated with rematerial-oriented design (ROD) are manageable by the designer and should be considered to understand and improve the process?*

To address this main question, it was necessary to answer the following:

- How can appropriate interactions among process, material and designer be distinguished logically within ROD?
- What processes, tactics and tools are currently adopted in design thinking that aims to generate and formalise ideas for upcycling?
- How do design decisions about remateriality affect the delivery of upcycled materials, elements or structures?
- How does ROD traditionally happen, and what are the implications for the awareness, effectiveness and efficiency of the process?

## 1.4 Objectives

Supported by these research questions, the following hypothesis was developed:

*The establishment of a framework for rematerial-oriented design can enable the development of more conscious, effective and efficient rematerial interactions.*

The aim of the study, therefore, was to improve rematerial interactions and thereby enable greater awareness, effectiveness and efficiency through the formal process of ROD. These criteria comprise adequate information flow and proper documentation (awareness); a satisfactory upcycling process (effectiveness), and reduced time and redesign incidents (efficiency).

The following objectives addressed the aim of the study:

1. Identify relevant factors related to process, material and designer, considering knowledge, tactics and tools currently adopted for problem-solving in ROD
2. Formalise the structure of rematerial interactions with identified factors, addressing related implications for the awareness, effectiveness and efficiency of the process
3. Establish support for ROD through a theoretical framework and a model for process improvement

## 1.5 Significance

The research is significant for three main reasons. First, the work adds value to the academic and technical fields, promoting an original exploration of design research for material re-contextualization and suggesting applied support for designers and do-it-yourself (DIY) practitioners involved in upcycling for architecture and interior architecture purposes.

Second, it presents a renewed focus on the importance of material during the design process and the opportunities inherent in material selection. Many contemporary projects are conceived in terms of volume, form, scale and assembly; however, this thesis demonstrates that material also must be a factor in design and provide a fresh look at the rematerial-oriented design process.

Third, it addresses the key issue of environmental sustainability, especially as it relates to waste generation and disposal of materials. By encouraging a lifecycle extension for resources that are frequently wasted, this study challenges main perceptions of waste and materiality opportunities.

## 1.6 Thesis Outline

This thesis presents a foundation for a better understanding of and support for rematerial-oriented design.

Part I consists of the research clarification (RC) and contains Chapters 1, 2 and 3. Chapter 1 introduces and contextualises the document. Chapter 2 presents the theoretical background to present the context for the ROD framework, provide evidence to support the research assumptions and adjust the conceptual framework in accordance with the findings. Chapter 3 explores the methodology adopted for the exploration of rematerial interactions, which was conducted for the empirical data analysis in the descriptive study.

Part II contains the descriptive study (DS) and includes Chapters 4, 5 and 6. Those chapters describe the structure of reflective, intuitive and skilful rematerial interactions in projects that were carried out to obtain a better understanding of the existing problem. Chapter 4 analyses the protocol of rematerial design tasks accomplished by experienced designers. The data generated by novice designers and by interviews with designers and

architects experienced in dealing with rematerial are presented in Chapters 5 and 6, respectively.

Part III deals with the prescriptive study. This section contains Chapters 7 and 8. Chapter 7 presents *conscious rematerial interaction*, the support formulated based on the results of research clarification and the descriptive study. This chapter complements the ROD framework, contextualises conscious ROD (the model for process improvement) and introduces *rematerial information modelling* (REMIM; the instrument for support). Chapter 8 concludes this investigation by delineating the contributions and constraints of the study and identifying opportunities for future research.

Appendices A, B and C incorporate the data explored throughout the projects focused on reflective, intuitive and skilful rematerial interactions as well as the coding structures and spreadsheets used for analysis.

## 1.7 Summary

This introductory chapter has established the research context, objectives and significance and outlined the document chapter by chapter. It contextualises rematerial-oriented design, points to opportunities and limitations in the field, and explores how the research aims to contribute to existing knowledge by offering an original framework for ROD and a supporting model towards process enhancement.

# Chapter 2 Theoretical Background

## 2.1 Motivation

The lifecycle of materials is one of the most significant discussions in the field of contemporary architecture. Chapman (2005) explained that within the past four decades, one third of the planet's resources have been consumed. Furthermore, most users are incapable of sustaining long-lasting relationships with products. For instance, in recent years, 25% of vacuum cleaners, 60% of stereos and 90% of computers are still functional when people dispose of them (Chapman, 2005).

The current linear trend in material flows encourages people to throw things away quickly, when they fall out of fashion or become outdated, often before they are physically worn out or technically damaged. This consumerist behaviour is alarming, especially when design seems to promote wastage instead of fostering sustainability.

Strasser (1999) stated that until the second half of the 20th century, most people could not afford this practice of quickly getting rid of clothes and household goods. Nowadays, however, possessions are discarded simply because they are excess, unwanted or no longer fashionable or because they have been designed for brief usage (e.g. packaging and disposable products). This is particularly true in developed nations.

Although waste is linked with consumerism, luxury and excess, it also constitutes a resource for subsistence and adaptation among deprived populations. As exemplified by Santos (2014), waste is used by homeless populations, for whom it may constitute material for constructing living arrangements on sidewalks; and furthermore, it may reintroduce collectors within the productive cycle. Usually, people living in poverty waste less and may seek out materials to use and to sell.

A report on the waste thematic showed that, in the financial year of 2006–2007, 43.777.000 tonnes of waste were generated in Australia; of this tonnage, 52% was recycled and 48% sent to landfill (Planet Ark, 2012). The Australian Packaging Covenant (2013) noted that, although the recycling rate for packaging increased from 39.2% in 2003 to 63.1% in 2011, almost 22 million tonnes of waste – most recyclable – are still sent to landfills each year. Of Australia's total generated waste, 29% is composed of municipal solid waste, 33% is produced by commercial office buildings and industries, and 38% originates during building, renovation and demolition of buildings, houses, roads and

other elements of the built environment (Planet Ark, 2012). Though the construction chain generates the largest proportion of waste, it also has the highest recycling rate of 58%, whereas only one third of municipal solid waste is recycled.

The need for intelligent repurposing in architecture has become a pressing issue today, but in other ages, it was completely apart from the society (Bahamón & Sanjinés, 2010). Architects and designers are largely responsible for the creation of the built environment and have made vast contributions to the waste stream. According to W. McDonough, Braungart, and Clinton (2013), the world has a design problem, not a pollution problem. It stands to reason, therefore, that architects and designers should be at the forefront of initiatives to reduce consumption, take maximum advantage of production and change design methods.

Solutions to environmental issues require actions in many fields. Wanderley, Gonçalves-Dias and Santos claimed, however, that “*design may contribute creatively, intelligently and consciously to the construction of new relationships between concept, production and consumption, based on more sustainable parameters that do not follow the standards of programmed obsolescence that still prevails at this time*” (Wanderley, Gonçalves-Dias, & Santos, 2014, p.117). Samsonow (2011) remarked upon the importance of this role and added that the solution lies not in reversing technological advances but rather, in evaluating how people so easily disregard everything that has been created in light of new technologies and products.

Stasser’s (1999) statement, “*What counts as trash depends on who’s counting*”, is reflected within this thesis. The definition of trash varies from individual to individual and place to place according to different social and cultural backgrounds and changes frequently. Objects may be classified as non-trash (what remains in the house) or trash (what goes outside). Marginal items may be stored in marginal places, such as attics, basements or outbuildings, to be used eventually, traded, or given away (Strasser, 1999).

This framework represents an important loss within the economy of material flows because it reflects a radical way of thinking wherein waste is synonymous with a problem. Thinking forward, Addis (2012) suggested that rather than seeing materials at the end of their first life as trouble, people should view these items as great opportunities to extend material lifecycles. Alternatively, materials could also be perceived considering the natural system of nutrients and metabolism: though there is waste in one system, that waste is food for another system. Therefore, waste equals food (William McDonough &

Braungart, 2002). Given the issue of materiality in architecture, the present proposal considers the stream of discarded and marginally classified materials as a valuable source of creativity in rematerial-oriented design.

Resource opportunities encourage ROD. However, the understanding of rematerial interactions depends on three main dimensions – process, material and designer – which should be considered differently in ROD than in conventional design. The next sections explore these dimensions and distinguish their existing logically appropriate connections.

## 2.2 Design Process

Design is a problem-solving activity in which assorted paths may be pursued throughout the definition of the problem to identify possible solutions. In rematerial interactions, the design process is one crucial factor that must be understood before advancements can be made. The assimilation of traditional design processes contextualises formal design concepts and general features that permit the appraisal of the specificities of ROD.

This section contributes to the recognition and delineation of the pertinent stages of design investigated in the projects 1, 2 and 3 (reflective, intuitive and skilful rematerial interactions) of the descriptive study, the second part of the thesis.

### 2.2.1 Conventional design process

#### Design methodologies

Since the second half of the 20th century, the increased complexity of manufactured products has led to the development of studies about product design methods (Bomfim, Rossi, & Nagel, 1977). Concomitantly, a fruitful new approach to the theme emerged from the realisation that design is common to various fields, such as engineering, industrial design, architecture and urban planning (Darke, 1979).

Burdek (2006) reported that, before 1970, the common thinking on design methodologies was based on Descartes' (1637) *Discourse on Method*, which proposed the decomposition of problems into minimal parts to achieve a general resolution based on partial solutions. More specifically, for Darke (1979), the design process that guided most of the research of the 1960s was based on an analysis-synthesis model. He argued that the complexities

of the process could be recognised as studies on design methods advanced and that the methods would emerge according to the level of complexity (Darke, 1979).

Van der Linden, Lacerda, and Aguiar (2010) stated that push to rationalise the design process culminated with the 1962 Conference on Design Methods in England, where research was presented on systematic and intuitive methods in engineering, industrial design, architecture and communications. The proceedings were edited by John Christopher Jones (1963).

Research on design methods widened to include other possibilities, such as scenario planning and scenario analysis, which were suggested by Kahn (1965). Lawson (1972) was notable for his exploration of problem-solving in architectural design, and Archer (1968) was known for developing attempts to structure the process through a series of papers that culminated in his doctoral thesis: *The Structure of Design Processes*.

However, Cross (1993) noted that, in the 1970s, some early pioneers, such as Alexander (1971) and Jones (1977), reacted against the formalisation of design. Cross appeared as a leading figure in the history of design method research both as a reviewer and a theory-builder. According to him, the second generation of design methodology in the 1970s and 1980s tended to diverge into architectural and engineering approaches, especially in the models of design processes. A third generation then derived from the previous two (Roozenburg & Cross, 1991).

Cross (1993) also noted that in the late 1980s, a broad renewal of interest on the topic emerged, particularly regarding developments in artificial intelligence, design automation and intelligent electronic design assistants. This expansion was accompanied by an increase in related journals, such as *Design Studies*, *Journal of Engineering Design* and *Design Issues* (Cross, 1993). Progresses in design methodology for the next decades include the categories suggested by Cross (1984), which delineate:

- the development of design methods, including product quality assurance, quality function deployment and design automation (Hauser & Clausing; Ross, 1988);
- the management of the design process, with systematic models in areas such as product planning and development and the architectural argumentative process models (Andreasen, 1991; Buur & Myrup Andreasen, 1989; Cross, 2008; Fischer, Lemke, McCall, & Morch, 1991; Hubka, 1982);

- the structure of design problems (Nazidizaji, Tome, & Regateiro, 2015; R. Oxman, 1990; R. M. Oxman, 1986; Rodgers, 2013; Donald A. Schön, 1984, 1988);
- the nature of the design activity, including protocols, case studies and empirical observations of the practice (Kim & Kim, 2015; Ozkan & Dogan, 2013; Donald A. Schön, 1984); and
- the philosophy of design method, which considers both design and science and explores their epistemology (Cross, 2001; R. Oxman & Oxman, 2010; Roth, 1999; Donald A. Schön & Wiggins, 1992; Suh, 1990).

Cross (1993) argued that, although design methodology has matured substantially in the academic field, it has had limited practical application because of lack of confidence or acknowledgement by design practitioners. This issue underscores the importance of establishing methodologies for updated and improved knowledge structuring and understanding, refining etymologies for research and architectural practice, and adapting the processes to foster the use of computational models.

## Design process representations

Many of the existing design methods are based on the segmentation of the process into steps. Van der Linden et al. (2010) reported that those steps usually include the following: (a) understand and define the problem; (b) collect information; (c) analyse the information; (d) develop concepts and alternative solutions, evaluate and re-evaluate alternatives, and select solution; and (e) test and implement.

In 2004, a comprehensive compendium of design process models was launched. This collection included more than 100 historical descriptions of various complexities from the fields of architecture, industrial design, software development, mechanical engineering and quality management. Although some of these models addressed the same processes, they represent differing approaches to design. Dubberly (2004), the author, classified the representations into six categories as follows: (a) analysis versus synthesis; (b) academic models; (c) consultant models; (d) software development; (e) complex linear models; and (f) cyclic models.

This section exemplifies some of these different categories of design approach representations. Recent research has recognised a focus on design activity (i.e. the design

process) as a means for process improvement rather than the more common focus on the deliverable (Blessing & Chakrabarti, 2009). Dubberly (2004) stated that in design, success depends on defining roles and processes in advance; documenting what occurs; and detecting and fixing fragmented processes.

Debates about design and development processes became more intense shortly after the Second World War (Dubberly, 2004). Cross (2008) argued that Archer (1968) was one of the first scholars to systematise these processes in a model. His proposal has elements of systematic observation and intuitive reasoning in the analytical phase and subjective judgement and deductive thinking in the creative phase step (as shown in Figure 2.1).

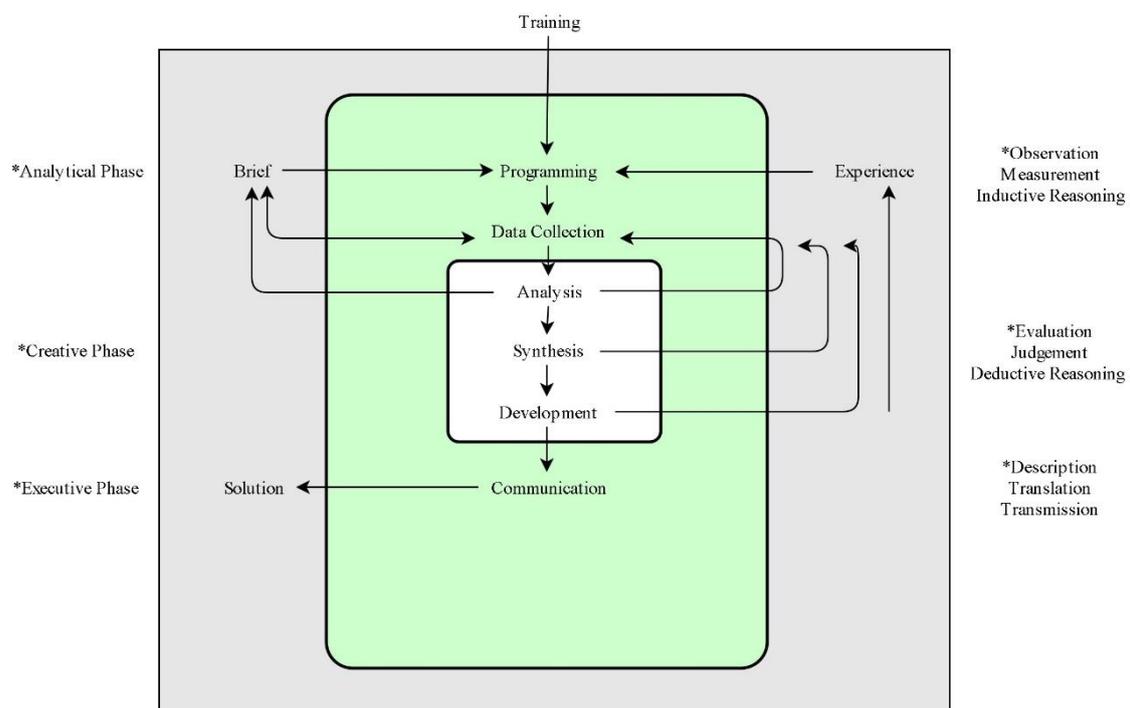


Figure 2.1. Archer's model for representing the design process. Adapted from Dubberly (2004).

Although some developed models share characteristics of linearity, alternative conceptions use cyclical flows; furthermore, there is always the possibility of returns and retro-alimentation. Asimow (1962) proposed another version that accounted for product lifecycle. The common phases from design (preliminary and detailed design) were followed by activities related to production, distribution, consumption and disposal.

James March broke the continuity of the linear models with a cyclic representation that includes production, deduction and induction (see Figure 2.2). In March's model, the first concept, production, encompasses the preliminary requirements to describe and sort

design concepts; deduction relates to forecasting performance; and induction refers to changes and concept refinements (Cross, 2008).

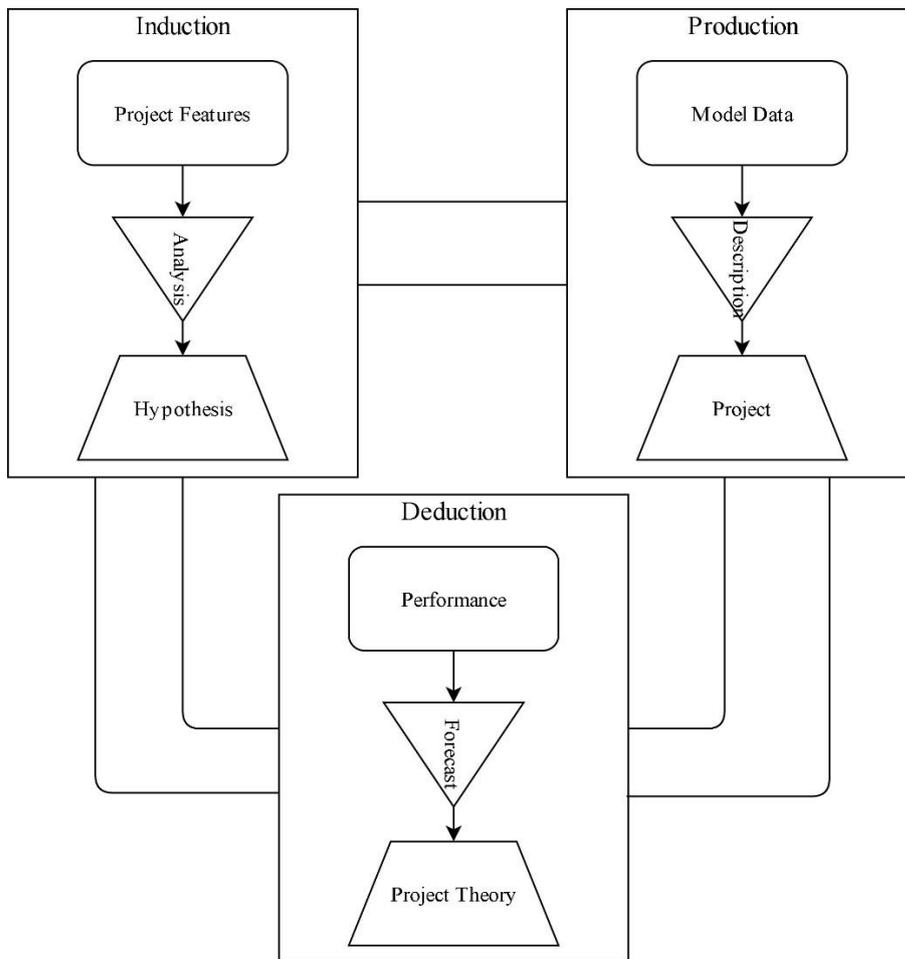


Figure 2.2. Design process representation by March. Adapted from Cross (2008).

Dubberly (2004) noticed similarities among design methods and structures in business and software development, and he pioneered the attempt to identify those points of resemblance. He argued that the fields overlap, but most designers, business managers and software developers seem to be unaware of the processes that exist in their own and other disciplines.

Another example of a non-linear model appears in the design process of IDEO, an international design and consulting firm. As stated by Tim Brown (2009), the CEO and president of the organization, this representation is a space system rather than a predefined series of ordered steps. As shown in Figure 2.3, this model appears chaotic upon first impression, but the multiple elements mark different related activities that, when coordinated, compound the innovative cycle.

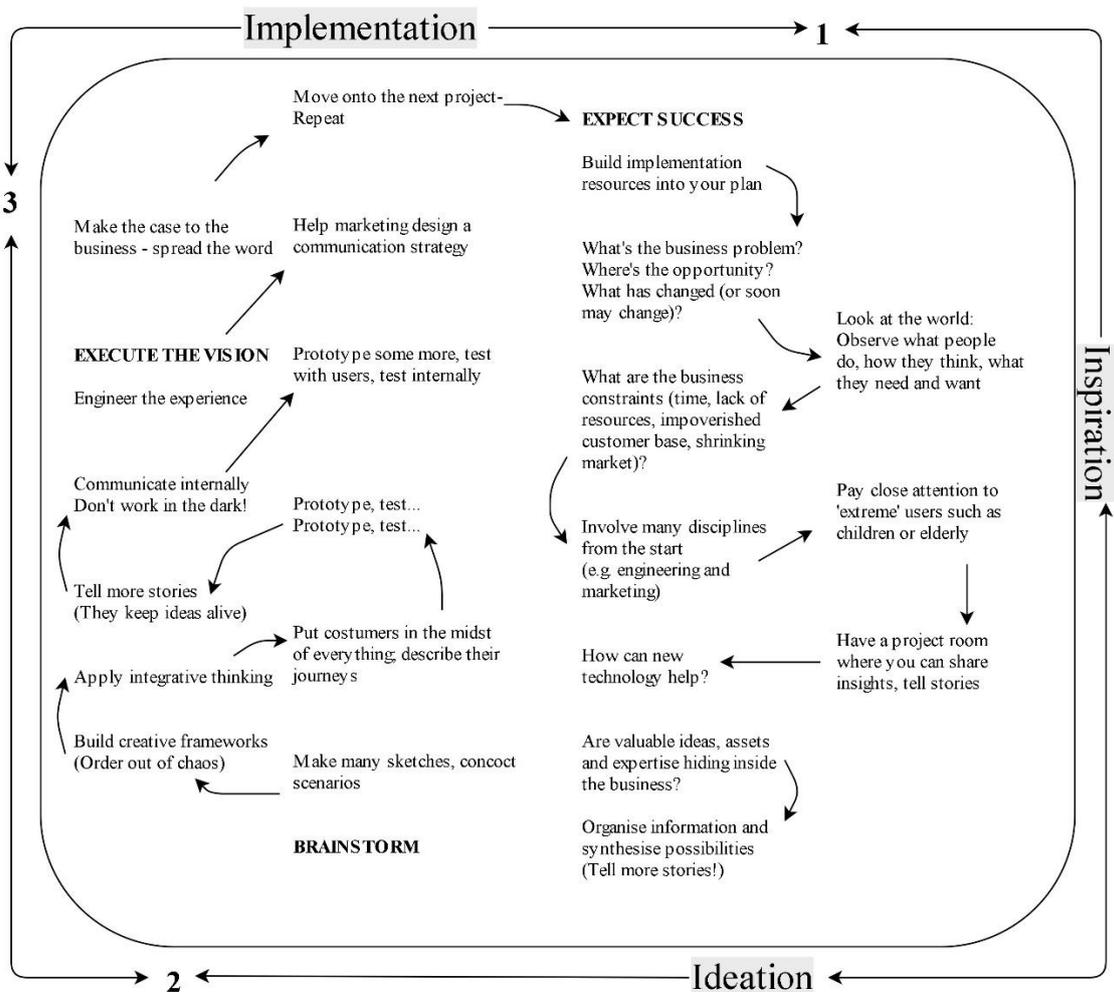


Figure 2.3. IDEO design thinking process. Adapted from Brown (2009).

Considering some of the academic attempts to frame the design process, the Design Council<sup>1</sup> (2007, 2014) proposed a simplistic but flexible linear model referred to as the double diamond (see Figure 2.4). This model represents moments of convergence and divergence in design decisions throughout the design development process, which begins with divergent thinking and develops until the ideas are selected and refined. Because of its comprehensive interpretation, the double diamond model is applied in this study to segregate and systemize main design moments and, consequently, facilitate understanding for further analysis.

<sup>1</sup> The Design Council is an enterprising charity that was established in 1944 in the United Kingdom. Formerly known as the Council of Industrial Design, it aims to use design to improve people's lives. The organisation proposes new design thinking, encourages debate and informs government policy (Design Council, 2016).

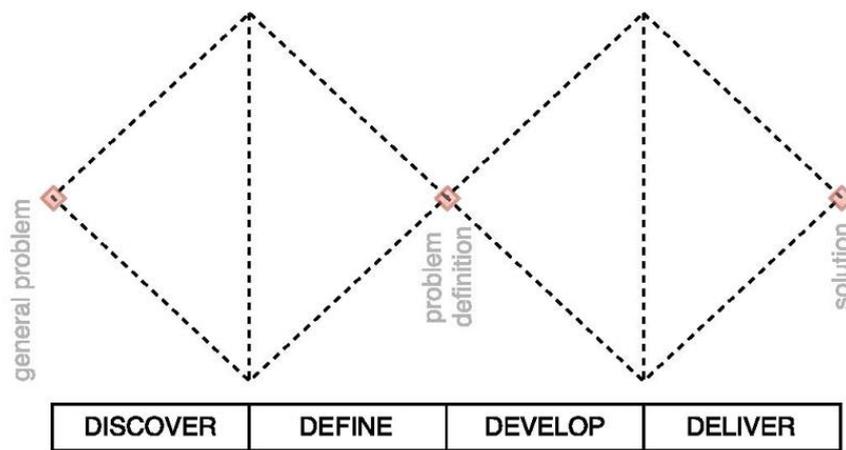


Figure 2.4. The double diamond. Adapted from Design Council (2007)

The four phases depicted in the double diamond can be explained as follows. Discovery is the first stage of goal establishment in ROD, and this phase is characterised by the moment when the potential application of presented materials, elements or structures has been identified but not yet cleared. This step also englobes the collection and absorption of material information. Definition happens during or after discovery and delineates the use of the available resource within design thinking. Development solidifies the goal and initiates idea materialisation through design documentation and further material learning. In delivery, a cluster of actions concludes the materialisation of the initially proposed goal or regresses the task for additional development or definition.

### Architectural problem solving

Across various fields, design can be interpreted broadly as a problem-solving activity aimed at complying with certain pre-requirements and meeting specific needs. As previously stated, it is the process by which concepts develop until they are meaningful enough to be represented through visual configurations and detailed enough to be read, understood and translated into real creations. Therefore, informed decision making in design requires research regarding the problematic. Critical thinking is essential to address many issues and leads to gathering information to answer questions relevant for solving the problem.

In architecture, notions of design range from the rational thinking of engineering to the intuitive ludic reasoning of the arts. It is fair to point out the narrow boundaries of interaction in these fields, with highly qualified engineers making use of intuition and creativity to untangle complex design problems. On the other hand, some artists also systematise or automate their methods to optimise outcomes.

Design problems faced by architects and interior designers usually relate to a vast spectrum of variables and requirements, including some that may not be tangible or measurable and a few that are strictly personal. Darke (1979) recognised that many factors must be considered in design problems but, contradictorily, believed that non-quantifiable factors were being transmuted progressively through research into quantifiable forms. Similarly, Gross and Fleisher (1984) argued:

“Design is a problem resolving activity that rarely provides a unique resolution. Architectural-like design, in subtraction, rarely results in answers that are entirely wrong. Many suffice. Some are suffered. A few are great. All persist. Validity at large is not provable. The choices that comprise design are not, therefore, arbitrary. The architect is an expert. But he rarely infers. He prefers.” (p.137)

Problem-solving in design involves more dimensions than function, cost, structural and aesthetic, and these aspects are challenging to evaluate. The approach must embrace senses, personal expectations (of both the designer and the user) and mood. Architectural process has wider influence than that of the arts because architecture provides both shelter and direct means of connection (or disconnection) with the environment.

Donald A. Schön (1988) pointed out that designers build their problem-solving processes through joint methods of perception, cognition and notation, not only through the shaping of materials. For Gross and Fleisher (1984), however, the process is all ruled by the constraints that frame the expertise, preferences, context, persons, places and institutions, circumstances, and the purpose and resources in addition to matters of taste, style and fashion.

Thus, architects tend to act mostly intuitively when they receive a design task, and according to Lawson (1972), they usually focus on the solution rather than the problem. Lawson identified two different attitudes towards problem-solving in design: problem-focused and solution-focused. A solution-focused attitude commonly is adopted by students of architecture. Instead of learning as much as possible about the structure of the problem before attempting a solution, they first try multiple solutions to see whether or why they go wrong (Lawson, 1972). This standard position segregates the activity from the benefits of process awareness and decreases opportunities for productive experimentation, preventing the discovery of a greater range of possibilities for conceiving the outcome.

The adoption of random and intuitive processes (with little organisation of thoughts, developments and short-term goals) may cause architects to miss latent proposals, overlook relevant criteria and conduct tests that are consistently unproductive, time-consuming and sometimes frustrating. This is not a general rule, however, as exceptional design solutions may develop from the first croquis.

Akin (1986) structured the architectural problem-solving process according to three major activities: problem representation, problem transformation, and searching. In this view, problem representation and problem transformation require a particular sort of knowledge, whereas searching involves matching resources with the current task (see Figure 2.5). The three sorts of knowledge applied within these activities are representational knowledge, transformation knowledge and procedural knowledge (Akin, 1986).

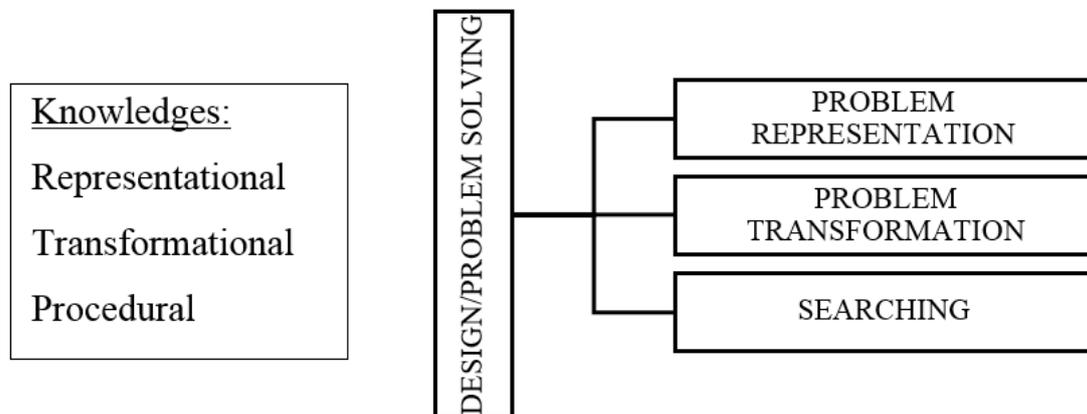


Figure 2.5. Problem-solving representation suggested by Akin.

In the architectural scenario, the inquiry process has influences beyond the search for specified products. Franz (1994) explained design as a mixture of rational interventions to process information, constructive processes to apply knowledge accrued from past experiences, and creative processes that draw on intuitive reasoning. Here, the designer must process two basic types of information: substantive information (i.e. in regard to the facts of the objective world) and procedural information, which indicates paths for understanding the current reality and matching knowledge and problem (Franz, 1994).

From another perspective, Markus (1969) listed four basic sources of information available to arrive at solutions for complex design problems. These sources include the designer's own experience, the experience of others, existing research and new research (Markus, 1969). Moreover, "*the central task of the architect is to discover the inherent structure of his problem and produce a three-dimensional expression of that structure*" (Lawson, 1972, p.84). The nature of the solution, however, is a function of the nature of

both the problem and the people who are attempting to solve it, which means that the design situation may change through variations of the problem and the natures of the solution and the solver.

In another point of view on problem-solving in design, Darke (1979) defended the idea of the primary generator, which consists of a comprehensive initial goal or a small set of goals that are self-imposed by the architect and emphasise judgement rather than rationality. In contrast, Wiggins (1989) divided the problem-solving process into two distinct realms, including substantive knowledge and process skills. The first concept refers to who the designer is and what he or she knows, whereas the second reflects the designer's attitudes and the overall decision framework adopted.

Design philosophies guide design methods, which contain a set of techniques for use in specified situations for data collection or analysis, problem description or solution, and simulation and evaluation (Lawson, 1972). Cross (2008) developed a flexible approach for selecting methods. In this tactic, he considered variables, strategies and cognitive designer styles (Cross, 2008). The starting point, however, is the definition of the strategy, which varies along with the nature of the problem and may be assertive in uncommon design situations.

The present study focused on the process for rematerial-oriented problem solving and shared Donald A. Schön (1988) approach, in which design knowledge and reasoning are reflected in designers' interactions with materials, artefacts made, and the conditions and manner under which they are made. Considering this approach, the three most important aspects for framing the investigation were identified in the reviewed literature. The first aspect is problem exploration (involving the rematerial) paired with problem recognition and exploration; the second element is the designer's substantive existing and future knowledge. The third aspect involves process skills, which account for the specific actions taken throughout knowledge construction and problem-solving.

## **Problem constraints**

A significant part of understanding the design problem lies in constraining its possibilities. The constraining procedure narrows the initial infinite possibilities to guide an informed decision-making process. It is essential to frame limitations, recognise factors and relations that deserve more attention, and impose coherence on the situation.

As declared by Donald A. Schön (1988), the designer must set the problematic design situation to formulate a design problem. The proposal proceeds from preference but is shaped by constraints and modulated by context and circumstance (Gross & Fleisher, 1984). Lawson (1972) argued that as the system of limitations in design problems increases, the range of possible solutions become more prescribed, and the freedom of the designer decreases. He identified internal, external and designer constraints as the three basic sets of limitations as follows:

“The internal constraint is composed of the various interactions between the variables of the architectural system being designed. An interaction is said to exist between two variables if they are not completely independent. Thus, if the architect alters the state of one variable and consequently finds he must change another variable, then these two variables are not independent. There is an interaction between them, and this interaction constraints the architect’s freedom.” (Lawson, 1972, p.51)

The importance of listing all relevant factors, analysing existing interactions and setting their performance limits was also highlighted by Darke (1979) and R. Oxman (1997). Only then should the designer start synthesising requirements for form generation. At this point, the need for subjective judgements (and the associated risks) decreases.

Gross and Fleisher (1984) suggested that designers consider the set of constraints to be “*a list of specifications unspecified and the connections they must satisfy*” and the process of design to be an enquiry into possible fixes.

In design involving rematerial, the design problem initiates with materiality, so the restrictions relate to interactions among the material, designer and environment. The material may be limited by its inherent properties and availability. Additionally, designers face external constraints, such as costs, time, tooling and labour, and must also recognise and cope with personal preferences, needs, substantive knowledge and design skills.

## 2.2.2 Rematerial-oriented design process

### Goal and means-oriented design

In ROD, the central theoretical focus is on the significance of the material within the design development. The expressions *means-oriented design* (MOD), also known by resource-based design, and *goal-oriented design* (GOD) were suggested by Taeke de Jong

(Van Hinte, Peeren, & Jongert, 2007). The approaches used to contextualise ROD may develop with a focus on goals or means. In GOD, the building goal is predefined; this is the most common approach, and it relates to conventional design methods in which every decision, including selection of materials, is made with the aim to reach the stated goal. In contrast, MOD begins with the means (or materials) available and has no defined ends or objectives.

Before this contextualization, these terms were used more commonly in relation to organisational cultures to define process-oriented versus results-oriented effectiveness within an organisation (Hofstede, 2005). In this case, institutional processes with elevated risks may benefit from means-oriented attitudes.

GOD is not a new idea but is used increasingly to extend the lifecycle of materials. The incorporation of salvaged or reclaimed materials in architecture requires an approach entirely different from traditional design, however. According to Addis (2012), in the traditional process, the design team first plans the structure up to the scheme or detailed design and then sources and purchases suitable materials and goods (as shown in Figure 2.6). In contrast, in a reuse framework, it is necessary to source and purchase goods and materials before embarking on the detail stages.

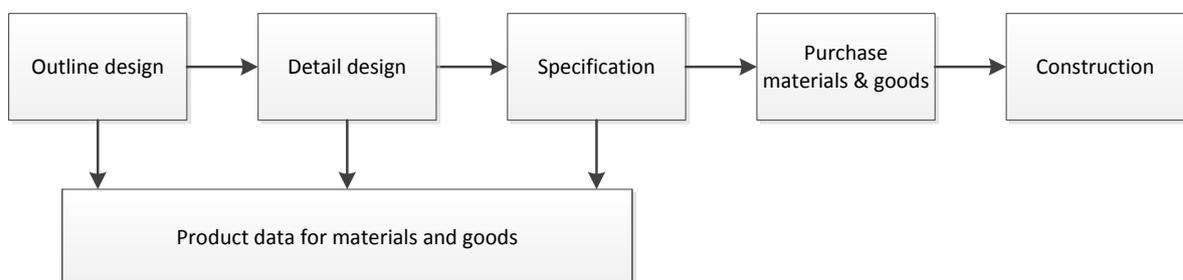


Figure 2.6. Goal-oriented design flow chart. Adapted from Addis (2012).

In conventional design (i.e. GOD), the architect conceives the elements and systems of building and then specifies the materials and components needed to achieve a given performance and quality. Generally, an established market for suitable materials and components already exists.

For goal-driven ROD, however, no equivalent market exists. Thus, it becomes essential for designers to identify sources of suitable products before they can undertake detailed design and specification (see Figure 2.7).

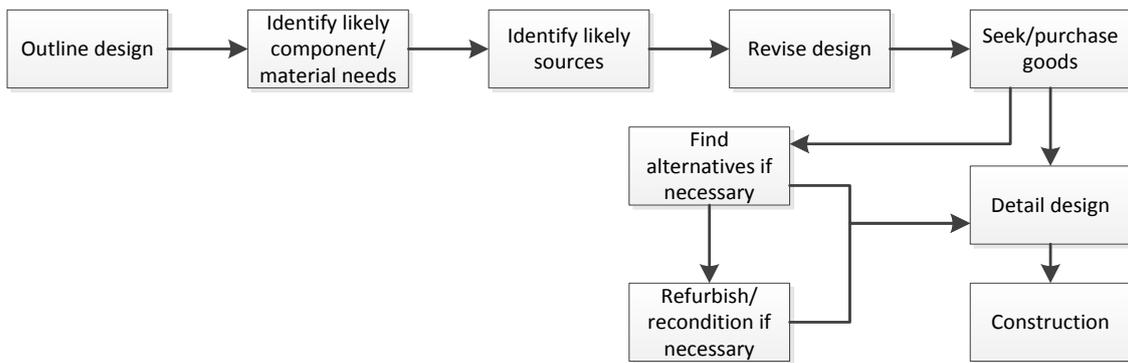


Figure 2.7. Goal-oriented design flow chart with reclaimed materials. Adapted from Addis (2012).

The design process becomes especially complex when the starting point is guided by availability of materials or goods. In this practice, designated as means-oriented design, designers focus on material first and then define objectives. Within this context, the establishment of design goals depends on factors related to means or materials, such as the availability of sources and the amount, condition, physical characteristics (form, appearance, resistance, flexibility, durability) and hybridism of the materials. MOD begins with limited resources, which lead the design towards a typically less pre-determined goal.

GOD and MOD processes are used worldwide to repurpose materials and have been common practices for designers who look at materiality as an opportunity. As stated before, however, such design approaches occur randomly in an ad hoc manner through an unstructured series of attempts and failures. Furthermore, these design activities are often approached as arts or crafts.

## Contemporary approaches

Regardless of whether the design focus is on the goal or the means, the interest in research and practices related to reuse, repurposing and recycling in design, architecture, landscape and the building sector is prescient. Recent publications such as *Superuse* (Van Hinte et al., 2007), *Building from Waste* (Hebel, Wisniewska, & Heisel, 2014), *Transmaterial* (Brownell, 2006) and *Rematerial* (Bahamón & Sanjinés, 2010) have presented inventories of architectural projects and construction elements using material that would be otherwise discarded. The exemplars originated from different institutional practices spread throughout the world.

Addis (2012) took a different approach to explore the factors involved in building with reclaimed components and materials in a handbook for reuse and recycling. Addis suggested an environmental preference method in which the ideal order for material re-contextualization is as follows: reuse, reclaim, recycle, and destroy. He further provided classifications, guidance and reasons for reuse as well as types of reuse (Addis, 2012). Some researches extrapolated the reuse and repurposing aspects and explored technological concepts for processing waste into new components for building materials (Brownell, 2006; Hebel et al., 2014). Other typical foci include design for deconstruction or disassembly, demolition management, adaptive reuse, construction with reclaimed material and design resilience.

At the building scale, adaptive reuse offers variations of material change-of-use refurbishment to improve the performance or capacity of a building, and that extrapolates to maintenance works (Council, 1993; Cowan, 1964). Studies have included directions for evaluating and making decisions about existing buildings with regard to current or updated usage (Bullen & Love, 2011; Burchell, 1981; Rabun, 2009) and critical inventories of buildings already adapted (Condello, 2016).

Since 2000, design for deconstruction has emerged as a common topic to address challenges and opportunities for maximising the reuse and recycling of materials pre-construction, during the design stage and within demolition scenarios (Addis & Schouten, 2004; Crowther, 2000; Fletcher, Popovic, & Plank, 2000; Gorgolewski, 2008; Thormark, 2001).

The ephemerality of modern and contemporary design is another point frequently stressed in the literature. Chapman (2005, 2012) and Hinte (2004), for example, reflected on designers' practices, consumers' expectations and responses, and the current consumer emotional detachment from materials.

Despite the growing body of literature on reclaiming material and design attitudes, these investigations predominantly have reflected on delivered projects, the agents involved in the process and their roles or aspects in managing materials, mostly within the context of recovered and recycled building components. There is a lack of academic inquiries into the design process, and design decisions made solely by designers are barely mentioned.

## Upcycling

The term *upcycling* was first used in 1994, when Reiner Pilz was interviewed by Thornton Kay (1994) for a newspaper article. The word also was used when Gunter Pauli's (1998) book, originally titled *Upsizing*, was translated into German by Johannes F. Hartkemeyer in 1999. The subsequent recorded appearance of the expression was in McDonough and Braungart's (2002) *Cradle to Cradle* in 2002; in this book, the authors, an architect and a chemist, respectively, differentiated upcycling from downcycling.

The words *upcycle* and *upcycling* were only recently added to dictionaries. The Oxford Dictionaries (2016) described "upcycle" as "*reuse (of discarded objects or material) in such a way as to create a product of higher quality or value than the original*", but more superficial definitions also exist, such as "*to make new furniture, objects, etc. out of old or used things or waste material*" (Cambridge Dictionary, 2016).

Within the recycling approach, it is important to distinguish rematerial-oriented design, upcycling and downcycling. The first implies that the material will be reused, repurposed or upcycled in an architectural or interior architectural setting. The resource will retain the same basic composition and may suffer preparation and minor to no modification. New uses, connections and installation procedures need to be implemented within this approach. Conversely, downcycled material results from items that have been processed and broken down to generate new ones. And while upcycling refers to the removal of wasted resources from their current situations to improved situations, downcycling purposes to reduce an article or substance into its components with the aim to reuse anything with potential utility. Downcycling commonly generates products of quality inferior to the original.

William McDonough and Braungart (2002) marked the thematic with a pioneer model of design and manufacturing to transform goods into biological and technical nutrients that will be natural food rather than waste. Since then, the number of publications from magazines, practitioners and businesses involving the terminology has grown substantially (Sung, 2015). In academia, however, the approach is prescient but remains restricted.

Recently published papers based on a review of the current literature (Sung, 2015; Sung, Cooper, & Kettleby, 2014) and described study cases (Richardson, 2011; Wilson, 2016; XU & GU, 2015).

In design, some books and PhD and Master's theses from the last decade have reflected the increasing interest in the theme: Bouffleur (2006) approached creative reuse and improvisation in product development and adaptation, whereas Balle (2010) and Van Hinte et al. (2007) promoted the development of resiliency in architecture through ecosystem biomimicry. Samsonow (2011) and Knecht (2011) explored architectural materiality with waste or scraps. Van Hinte et al. (2007) introduced the means-oriented design approach adopted by Zjawin (2013). Aus's (2011) doctoral thesis, *Trash to Trend*, envisioned textile upcycling, and Silva (2014) discussed the upcycle of furniture.

López (2014) and Sartori (2016) were the first to propose design processes improvements similar to this study. López (2014) developed a platform to improve upcycling and do-it-yourself attitudes that could be implemented within a certain company that trades industrial offcuts, mainly plastic. Sartori (2016), in contrast, attempted to propose an incipient support system for generating ideas in the beginning stage of design.

*The Upcycle* by (William McDonough & Braungart, 2013) was a follow-up to their 2002 book, *Cradle to Cradle*, and presented a retrospective view the changes that had occurred in the decade after the initial theory was proposed.

Despite the increasing attention to the theme, upcycling as a practice will remain marginal within the field at least for the foreseeable future, while resources to produce new products from raw material are cheap and readily available. Although the literature on processes and definitions is yet raw and contradictory, the activity has been encouraged as a means to extend the lifecycle of materials. This study focused on materiality from discovery to the re-contextualization of available resources, providing uniqueness and an audacious approach to a particular project.

On the one hand, Szaky (2014) believed that object upcycling is one of the most interesting circular solutions in the waste hierarchy given its location between reuse and recycling because it typically requires little energy input and eliminates the necessity for a new product. McDonough and Braungart (2014, 2002), on the other hand, defended radical design transformations for everlasting cyclical material reuse. Knecht (2011) proposed a ground breaking approach for upcycling that is more engaged in materiality exploration than a sustainable, green or eco-friendly activity.

There are numerous advantages in the standard systems, but architectural upcycling is not just a sustainable practice given the contribution to reduce waste generation. Rather, it is

meant to be provocative and polemic, touching the imaginary and bringing the realm and magic of materials back to architectural design. Comparable to a craft activity, upcycling approximates the designer and the maker.

Within the architectural scenario, however, the process is complicated when the proposal is to carry out the design process in which the availability of materials or goods guides the proposal. Within this context, the establishment of design goals depends on factors related to means or materials, such as availability of sources and the amount, condition, physical characteristics (form, appearance, resistance, flexibility, durability), and hybridism of the materials. The process begins with restricted resources, which lead the design towards a less pre-determined goal. It usually occurs via an unstructured series of attempts, failures and improvisation and is often approached as a craft activity.

## 2.3 Materiality

ROD is about material re-contextualization. Architect's proper interactions within the process conveys to upcycled objects, elements and structures. During design, the material is reframed from its usual position within the architectural problem to be perceived as another important dimension of ROD. Thus, it is pertinent to address the role of materiality in typical design and aspects of its exploration and explore the circumstances that make rematerial opportune for design. This section clarifies the value of materiality in ROD and indicates material information explored in projects 1, 2 and 3 of the descriptive study.

### 2.3.1 Architectural material practice

There are different views about the meaning of materiality within architectural development. Some contemporary practices disregard materials in the early stages of design and consider them only during the detailing or delivery stage of the project. Others guide their conceptualisations through materiality intentions or even prioritise matter over form. Despite the diverse views of conventional design structure, the design process invariably begins with a focus on a particular problem or need, which may be directly connected with material. To achieve a favourable response to a design question, the designer makes use of different tools and methods, and the range of possibilities for the outcome depends not only on how those are applied but also on the background developed prior to the launch of the design process.

Materiality has an important role in architectural design because it affects all aspects of spaces and buildings. These spaces are dynamic and evolving and present an interplay of light, materiality and narrative, and all formal and tectonic explorations should contemplate the interdependence of these components (Zarzycki, 2006). According to D. A. Schön (1992), architectural design is an *“experimentation that consists of a reflective conversation with the ‘materials’ of a design situation”*. Designers often select different objects or even choose the same objects in several ways to narrate different meanings and design stories (D. A. Schön, 1992). The use of recycled materials in architectural design, for example, is a sample of such design innovation.

Architecture is a material-based practice with an emphasis on the consideration of materials from the conceptual stages of design to the building delivery stage. With advances in technology and specialised knowledge, the roles of designer and maker have become distinct. As the body of representational knowledge has grown, reflection on and understanding of materials in architectural design has decreased in contemporary practice. Architects have been viewed as form givers who relegate material to the empty spaces between lines. For instance, in contemporary professional practice, drawings describe form, whereas language is used to describe materials in notes on working drawings and in the specification (Thomas, 2007).

As Temple (2011) argued, although designers must be learners of materials, most of the time, they only envisage how an object will look or act. Also, university students are often encouraged to model using only white or other neutral, single-colour materials. The actual connection with materials through processes and tooling is often relegated to others. This approach places architectural design as a mode of representation and reduces a building to an assembly of material systems.

Materiality in architectural design remains a broad topic. Technological advances have offered endless possibilities for materials in every application in design. The array, however, is so extensive that it is a challenge to make a proper selection considering the management of the knowledge about the range of material property data (Fernandez, 2006; Mike F. Ashby, 2010). Wright (1945) added that there are *“just as many fascinating different properties as there are different materials that may be used to build a building will continually and naturally qualify, modify and utterly change all architectural form whatsoever”*.

The emphasis on materiality in the design process is not new. In 1938, Mies van der Rohe already had argued that “each material has its specific characteristics, which we must understand if we want to use it. In other words, no design is possible until the materials with which you design are completely understood”. Conversely, materiality in the arts is considered explicitly at the outset of the creative process. For example, this is well explained in the documentary *Wasteland*, in which Walker (2011) emphasised the typical manner of museum visitors, who examine the artwork from near and afar to comprehend the complex relations between matter and image and to experiment with the surprising connections that make sense in art.

The concern with meaning subtraction has brought to design research and practice new topics on materiality, and other improvements in practice have renewed interest in architectural materiality. The contemporary resurgence of interest in materials has occurred for several reasons. First, sustainable architecture – supported by years of research - requires detailed knowledge about sources, fabrication and the transportation process, as well as labour and economic conditions that influence the production of materials. Second, the use of nanotechnologies to engineer new smart materials has increased the opportunity to specify material behaviours and considerations regarding performance in addition to appearance. Within the emergent inventory of innovative materials, several groupings exemplify these changes. Brownell (2006) specified seven categories for design materials: ultra-performing, multidimensional, repurposed, recombinant, intelligent, transformational and interfacial.

Thomas (2007) emphasised the importance of material exploration in architecture and the necessity of being open to the potential inherent in new and old materials and gaining an understanding of how these materials may be productive not only in terms of space but also experientially and politically. Schröpfer et al. (2011) concluded that materiality is not only related to structural and aesthetic categories but also is sensorial, ideological, structural, performative, economically viable, new or outmoded in contemporary culture. For these researchers, the material meaning is mutable.

## Material embodiment

In most buildings, materials are determined by “local availability, current practice and experience, cost and construction expediency, and to a lesser extent, design and aesthetic preferences” (Fernandez, 2006). The material, however, can utterly transform architectural conceptions.

In traditional design, the first stage for material embodiment is the process for selection. There are numerous methodologies for material selection in engineering and industrial design. Mike F. Ashby (2010) suggested some of the following methods for product design: by analysis, by synthesis, by similarity, by inspiration and by a combination of these methods. Jahan, Ismail, Sapuan and Mustapha (2010) proposed two categories of methods. The first, the category of materials screening methods, included the cost per unit property method, chart method, questionnaire method, materials in products selection tools and artificial intelligence methods. The second category, which consisted of materials comparing and choosing methods, included multiple attribute decision-making approaches, fuzzy multi-criteria decision-making methods, multiple objective decision-making methods and optimisation methods (Jahan, Ismail, Sapuan, & Mustapha, 2010).

In architecture, however, the designer looks for experimentation, sensations and specific tactile properties, and these tools consider only technical aspects. The requirements, such as quantity, form, function, properties and even budget, are usually known for any particular task, but the material itself is rarely known. Usually, the criteria are based on the designer's background, experience or knowledge or are guided by standardisation or stakeholders' interests. Some few borders their choices on libraries of materials in computer-based tools.

Wastiels and Wouters (2009) identified four themes of material selection considerations in architecture: (a) material properties, (b) experience, (c) manufacturing process and (d) context. Peter and Paul (2012) proposed the Use of Leadership in Energy and Environmental Design (LEED) rating system for building materials selection. Fernandez [8] stated that contemporary architects mainly makes choices that result in "fabricated assemblies of standardised performance attributes", implying that they do not select for materials but rather for material systems. He also argued that limiting the assembly of buildings to the specification of systems would impede the discovery of design possibilities through materials (Fernandez, 2006).

An effective material embodiment process might narrow the range of potential errors and increase design opportunities in architecture. Compared to the guiding principles of engineering design, the perception level required to select material in architecture relates to form, function, interaction, virtual perception and even the non-perception of the material rather than being based on the cost, strength, availability or environmental compatibility (Soliman, 2013).

According to Knecht (2011), extrinsic and intrinsic material characteristics are decisive because they empower or restrain potential application within the proposed assembly. Although intrinsic properties are habitually quantifiable, the extrinsic ones are usually connected to subjective factors, such as sensorial, emotional or cultural issues.

This context makes explicit how, in design for upcycling, the problem bears mainly on the material. The resource is essential to the first stage of design and is the starting point rather than an object for later selection and specification. Additionally, material must be learned rather than selected, and it should be prepared (reconditioned or refurbished), which requires full understanding of its properties and condition. These aspects of material selection deserve special consideration as potential factors related to the efficiency of ROD.

## 2.4 Designer Knowledge

The designer represents another pivotal dimension of design. The outcomes of an interaction will depend on what he or she knows (the pre-existent and constructed knowledge), the process adopted and what he or she does (process skills). In short, the designer is the manager of the information flow throughout the project. ROD, given its customised character, demands familiarity with making to decrease the prospect of failure or the need to redesign.

This section refers to the effects of experience, skills and strategies in design processes and supports the definition of design approaches that are explored in projects 1, 2 and 3 of the descriptive study, referring to different levels of ability with design or rematerial.

### 2.4.1 The conventional designer

#### Level of expertise

Designers have different levels of knowledge and expertise. In an attempt to point factors related to the design ability, Lawson (1972) observed that both innate, hereditary aspects and educational issues contribute to quality final working solutions. The master designer has had more opportunities for reflection and transformation throughout the many trials and errors of his or her career and has built a path which the beginner is only starting to walk (Temple, 2011)

During their time in university, novices are taught means for developing design abilities and they are trained to deal with problem-solving within various architectural schemes and complexities. However, instructors presume that they will build their individual work methods throughout their careers by learning by doing (Kavakli & Gero, 2003; Welch & Lim, 2000). Though this is a recognised educational tactic with positive outcomes (Anzai & Simon, 1979), theorists still lack the exact details about how such knowledge is acquired, aggregated, transmitted, and embodied in a design production setting (Wible, 2013).

In many educational design institutions, the core proposition of learning by doing is often misinterpreted as the extensive use of activities that rest on abstract models, such as analytical and visual thinking or representation. Temple (2011) suggested that such exercises are reductive, often removed from reality and with little or no contact with real materials and space. Immersion in physical making and the discovery of materiality enables factual learning and allows the transformation of tangible experiences into mental operations (Temple, 2011).

Welch and Lim (2000) found that apprentices order their design processes contrary to suggestions. Even though they usually receive guidance from tutors and lecturers, most create unique paths to design solutions. They do not explore many alternative solutions and thereafter select the most efficient. They also do not apply three-dimensional modelling in a superior manner and neither use as much two-dimensional modelling as is suggested by the textbooks.

In the early stages of learning, intuitive making is the relatively common approach adopted during the design process. According to Ahmed, Wallace, and Blessing (2003), novice designers have a propensity to think backwards and apply deductive approaches, whereas experienced designers tend to reason forwards or to alternate between forward and backwards reasoning when facing complex design situations.

It is appropriate to remark that initially, pupils will lack cognizance and will, therefore, disregard relevant aspects within a design proposal (von Hippel & Tyre, 1995). Eventually, most will acknowledge that these considerations are important. Nevertheless, some considerations will continue to be overlooked given the infinite possibilities that drawings, sketches and rough prototypes allow during a project development.

Regardless of level of experience, designers have four primary sources of information available when facing a complex problem: personal experience, the experience of others, and existing and new research (Markus, 1969). Interestingly, Schon and Wiggins (1992) argued:

“Design knowledge is knowing in action, revealed in and by actual designing. It is mainly tacit, in several senses of the word: designers know more than they can say, they tend to give inaccurate descriptions of what they know. And they can best (or only) gain access to what they know by doing.” (p.03)

Moreover, in Lawson’s (1979) investigation into cognitive problem solving by architectural students, the researcher claimed that architects are taught mostly by example and practice and are judged by the outcomes rather than the methods applied. Contrarily, scientists are taught through a succession of concepts and are trained to apply those principles in real cases.

The fundamental differences identified between expert and novice designers established a close connection between strategy and performance. Experts’ cognitive productivity was approximately three times higher than that of novice designers (Kavakli & Gero, 2003). Despite the lack of deep technical awareness, however, the creative exercises developed by students commonly generated the purest results and were focused mainly on primary principles of decomposition, conceptualization and formal creation. Moreover, novice abstains from bias and boundaries that limit design solutions (Ozkan & Dogan, 2013; Welch & Lim, 2000).

## Precedents

Prior design exemplars are widely accepted as important sources of knowledge in the creative design process. In accessing them, the designer may refer to past answers to solve current design situations and identify factors already considered within different contexts. The practice of selecting relevant ideas from past design problems to address present circumstances is known as *precedents-based design* (PBD; (Eilouti, 2009; R. E. Oxman, 1994) or *case-based design* (CBD; (Chakrabarti et al., 2011; R. Oxman, 1997), which is related to the computational paradigm of *case-based reasoning* (CBR; (J. Kolodner, 2014).

Case-based reasoning refers to “*adapting old solutions to meet new demands; using old cases to explain new situations; using old cases to critique new solutions; or reasoning*

*from precedents to interpret a new situation [...] or create an equitable solution to a new problem”* (J. L. Kolodner, 1992). In design, R. Oxman (1997) defined CBD as *“the formulation of approaches and processes to the ‘adaptation’ of designs, or the modification of past design representations to fit a current design situation”*.

Baxter (2000) stated that the CBD approach is based on the evaluation of patterns. In this view, precedents may be accessed through their description of the material specification and development process; innovations and standardisation concepts; assembly procedure; technical drawings and models; tests outcomes and demonstration; and prototypes showing physical features (Baxter, 2000). R. Oxman (1994) highlighted that when exploring design ideas through precedents, designers seem to accomplish free and associative browsing between multiple precedents to establish relevant connections and discover original and sometimes unanticipated design concepts.

Eilouti (2009) also suggested PBD as a mechanism for describing previous formal, functional, structural and semantic solutions systematically to identify, partially or wholly, innovative design solutions relevant to the problem. In this proposal, it is feasible to extract relevant information and organise it into significant layers to reuse in new projects (Eilouti, 2009). Alternatively, Oxman (1994) proposed an approach to design decision support systems through computer-based libraries of design precedents. Such structures may be an effective formalism for encoding relevant design ideas and can enable the representation of complex and rich knowledge through the division of design examples into flexible portions of information (Oxman, 1994).

Besides the precedents that have been methodologically defined, designers commonly rely on references for analogical reasoning. Here, they are not looking for precise precedents (in the way layers are) but rather are seeking any orientation, sourced frequently from different domains to the design situation, that may somehow be useful (Goldschmidt, 1998; Menezes & Lawson, 2006).

In this context, Goldschmidt (1995, 1998) suggested alternatives to formal systems of precedent-based thinking. Goldschmidt found these formal systems counterproductive to promoting design creativity and claimed that architectural and other exemplars are more ambiguous and manipulable and, therefore, more creative than formal archetypes, such as precedents. Designers, she argued, benefit from general imagery to extract information for their task in hand, particularly when a display is imprecise, unfinished and open to multiple interpretations:

“References comprise any relevant information for quick display, when their consideration about a design task appears relevant or potentially relevant. A system of references is superior to a system of precedents because its wider scope, its less authoritative nature, and its higher level of personal adaptability are better suited for the support of creative design processes.” (Goldschmidt, 1998, p.269)

In the early stages of the design process, analysis of prior exemplars allows for diverse strands of problem interpretation and contextualization, decomposition, and response demonstration. During the refinement process, the analysis also provides a data library for future interventions because it allows designers to observe, adapt and combine methods until an optimal solution is found. In the final stages, comparison and evaluation of design outcomes with previous results for similar issues can be applied to critique the entire cycle (Barros, 2011).

### Architectural representation

In the preceding sections, the relevance of understanding the design problem and accessing direct or indirect knowledge for resolving the task at hand was discussed. It was also noted that different problem solvers with diverse levels of skill and experience would approach design situations differently. However, the assumption that architects think, experiment and communicate through representation techniques rather than applying systematic approaches for problem clarification and solutions is widely prevalent (R. Oxman, 2002; Rowe, 1987; D. A. Schön, 1992; Schon & Wiggins, 1992; Suwa & Tversky, 1997; Temple, 2011; White, 1992).

During the architectural process, both the problem context and the development of design solutions are necessary to be represented (Maller, 1991). Thus, designers approach graphical reasoning and design representation as an externalisation of conceptual knowledge structures and creativity using visual means (R. Oxman, 1997). Architectural designers, especially those with more experience, rely heavily on some common design strategies related to representation, such as drawing and modelling, which may include bi-dimensional or tri-dimensional representation. Drawing includes sketches and drafts created by hand, digitally or a combination of both. Similarly, models may be constructed manually (physically) or through computational tools (digitally). They configure support for design reasoning, ideation, information transfer and communication.

Architects represent things to be built, which enables them to experiment at relatively low risk and cost while making sketches, drawings, diagrams and models to function as virtual worlds (Donald A. Schön, 1988). That graphical material, which can even include hand-written memos, not only assists memory but also simplifies and constraints inference, problem-solving and understanding (Suwa & Tversky, 1997).

Parallel to the hand-made representations, the introduction of computer-aided design (CAD) and computer-aided manufacturing (CAM) into the process has changed the role of drawings and models within architectural development. These tools facilitate manipulation, transformation, visualisation and communication of design objects; provide increased precision and speed; and enable the consideration of multiple alternatives for problem-solving. These technologies also may support specialised studies, such as research into structural, environmental or acoustic factors, through specialised software and simulators.

Computer models are useful for creating complex shapes and may mediate the design process and the construction stage. Parametric modelling or CAD scripting is apt to generate complex forms with intuitively reactive components, enabling the maker to elaborate structures previously too laborious and geometrically complex to realise (Pitts & Datta, 2009; Sass & Oxman, 2006). Moreover, digital design fabrication (DDF) has emerged as a method that represents the integration of generative computing and rapid prototyping (RP), in which objects are built through digital media and printed tri-dimensionally as candidates for design solutions in the early stages of creation (Barros, 2011; Celani, 2003; Sass & Oxman, 2006).

Digital advances also have provided the opportunity to generate information models, such as the design information models (DIM), which represents the design development and includes some preliminary levels of construction documentation (Sass & Oxman, 2006; Shooter, Keirouz, Szykman, & Fenves, 2000), and the building information model (BIM; (Eastman, Eastman, Teicholz, Sacks, & Liston, 2011; Lévy & Lâevy, 2011; Sanguinetti et al.; Sass & Oxman, 2006), as a digital model linked to sets of information regarding a building that can be maintained, accessed and updated throughout its lifecycle.

Despite all the opportunities presented by digital technologies, they should be used with caution. Celani (2003) argued that restricting approaches to purely digital methods may have a negative influence on the designer's response to a design problem, especially if he or she has limited experience. McCullough (1996) remarked that when there is a lack of

computational skills, the designer's efforts and attention may be diverted from handling the design problem to dealing with the machine. Additionally, Righi and Celani (2008) and (Poole, 2007) advised serious reflection when adopting solely digital strategies for design because hand drawings may be synthesized ambiguously and can play an important role in creativity and problem exploration.

## Digital craft

As highlighted in the preview subsection, recent developments in technology have heightened the need to renew the production of architecture and urbanism. Digital tools have affected all phases of design from the first sketch to the production and assembly of building components. These tools offer possibilities inconceivable just a few years ago, but they also raise numerous questions regarding the challenges of integrating digital technologies with architectural design and their ability to maintain reliable quality with results similar to those shown during modelling.

On this issue, Poole (2007) questioned how advanced digital technologies and computational velocity have changed the way to give shape to our imagination. According to him, the speed at which drawings and images can be conceived and produced has increased, and so has the rate of exchangeable data. His study, however, indicated that although rapid prototyping methods allow designers to fabricate and arrange three-dimensional objects quickly, it gives the designer little insight into how the object could be mass-produced. Furthermore, the speed of these digital processes allows designers little or no time to analyse creations, allowing them to set unreal conditions under the assumption that is no limit to formal conception (Poole, 2007). Thomas (2007) further noted that digital-based mechanistic processes, such as computer numerically controlled (CNC) and digital design fabrication (DDF), with rapid prototyping, enable a direct link between conceptualization and production.

Dunn (2012) is probably one of the best-known practitioners of digital possibilities. Whereas Poole (2007) asserted that the synthetic smoothness of computer-generated images produces a false sense of technical resolution, Dunn (2012) claimed that visualisation techniques bring life to imagination, allowing designers to generate more extreme and accurate scenes. He added that "*architecture is fundamentally concerned with two core activities: designing and making*" (Dunn, 2012, p. 6); furthermore, architecture is concerned with using digital tools because designing for materialisation embraces both. As stated by Bechthold (2007), design thinking was affected deeply by

the emergence of powerful surface and solid modelling tools, which allowed complex three-dimensional to be produced with a digital process. Even though this statement is partially true, it contains inconsistencies. To carry out the complete design process, designers must make previously detailed considerations relating to structural limits and material features as well as technical expertise and skilled labour. Whatever their opinions on limitations of methods, a large and growing body of scholars equally agree that digital tools offer powerful, speedy, productive, scalable and precise data production and a manufacturing platform for architectural design and production.

Nevertheless, researchers should be aware that the development of design methodologies proceeds more slowly than the development of computer-supported tools. Precise and sometimes customised interactions between methods and tools will provide better support in making decisions. Thus, there is a need to adapt design methods to be used in combination with various tools according to the design problem (Birkhofer, 2011).

Traditionally, digital design practices are considered to be efficient and numerically precise ways of operation. On the other hand, craft is often relegated as follows:

“[It is the] realm of amateurish making, complete with mistakes, dropped stitches, fingerprints or other traces of human fault that are understood as being charming in the context of handmade human endeavour yet fall short when measured against ‘serious’ artistic categories that include architecture, design and fine art.” (Roke, 2009)

For many thinkers, however, digital manipulation is an advanced craft through which mixed tools need to be applied to reach the final goal or meaning. Both Roke (2009) and McCullough (1996), for example, proposed that craft need not be limited to the physical world – creating electronic forms also can be a rewarding, hands-on experience.

When analysing concerns about design process becomes *“less a matter of putting oneself in the job and more about getting the most out of the machines”* (McCullough, 1996p. 16), Boza (2006) observed that one should focus on innovation and efficiency as well as intuition and creativity. For the researcher, systematically defined process of design and fabrication can be coupled with an intuitively responsive process through the hand’s physical contact with the material. In this way, the designer or craftsperson gains experience and develops more refined knowledge about material manipulation and tool usage (Boza, 2006).

ROD is a craft activity of experimentation. It requires substantive knowledge, such as creativity, repertoire and spatial visualisation capability.<sup>2</sup> Thus, computing allows all these activities to be performed virtually, minimising errors and failures during the process and improving value. Digital technology also can facilitate the basic structure of seeing-moving-seeing<sup>3</sup> in design. To these advantages, Chakrabarti et al. (2011) would add that digital tools can help designers explore new directions through a wider variety of possibilities, expanding the range of solutions considered manually. They also can decrease the tedium of routine design tasks by automating them, leaving more time for creative activities. Technology, thus, can become a catalyst for humanising opportunities rather than an end to the means (Boza, 2006).

## 2.4.2 Rematerial-oriented designer

### The upcyclers

As well as the designer, upcyclers are also problem solvers. Though they are not necessarily aware of their inherent role, they have a clear objective to exteriorise ideas through an attitude of work that re-contextualises material into an improved position. Designers and architects who adopt upcycling have developed their own tactics for incrementing creativity and further knowledge on rematerial interactions. Upcycling is aligned with the process of making; therefore, the relationships among upcyclers' ideas, abilities, materiality, processes and tools are extremely close.

As reported by Strasser (1999), making and fixing things have become hobbies and are not as typical as they used to be. Nevertheless, the Maker Movement, declared as the new industrial revolution, has focused on rescuing this practice and enabling individuals' interactions with objects that go beyond consumption (Dougherty, 2012; Morin, 2013; Swan, 2014). However, to repair and find new applications for worn and broken items demands consciousness about materials. Transformational ideas are more frequent among people who make things and for being handy at changing things, so there remains a need for a tactile material understanding.

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<sup>2</sup> Spatial visualisation, according to McGee (1979), is the ability to mentally manipulate, rotate, twist or invert pictorially presented stimuli presented. Other definitions presented special visualisation as the ability to visualise imaginatively some volumetry and its transformation (Gorska, 2003).

<sup>3</sup> This expression is Donald A. Schön and Wiggins (1992) well-known description of the design process whereby designing enables new discoveries for redesigning.

This view brings upcycling activity adjacent to workmanship, craftsmanship, the bricoleur and the DIY practice. Some authors have claimed that the boundaries of action among these groups overlap (Atkinson, 2006). Strauss (1962) is well known for his bricolage framework and for describing the differences between the bricoleur, the craftsman and the engineer:

“[...]‘bricoleur’ is still someone who works with his hands and uses devious means compared to those of a craftsman [...] It has to use this repertoire, however, whatever the task in hand because it has nothing else at its disposal [...] The set of the “bricoleurs” means cannot therefore be defined in terms of a project [...] elements are collected or retained on the principle that ‘they may always come in handy’.” (Strauss, 1962, p.11)

In another perspective that also linked design to craft, Pye (1968) aligned workmanship and related risks with three main variables: material, tools and technique. This position remains appropriate. According to the author, the practice depends on a near relationship between the design intention and the process to execute it. The level of appropriateness of the variables will determine the risk and, consequently, the outcome (Pye, 1968). Temple (2011) argued that although design anticipates and delineates constraints, it is the maker who ensures the control. During a project, constraints will emanate from various sources, such as trade practices, materials, tools and the skills of the worker.

DIY, however, comprises “*a more democratic design process of self-driven, self-directed amateur design and production activity carried out more closely to the end user of the goods created*” (Atkinson, 2006, p.1). DIY practitioners may also be upcyclers. They represent a growing mass of individuals who fix, build, install and modify things on their own. López (2014) remarked that the current easy access to information via the Internet has increased the movement toward self-sufficiency in which enthusiasts aim to improve their skills through learning instead of relying on paid services.

Based on the above discussion on bricolage, craftsmanship and DIY, before starting a rematerial project, the person aiming to upcycle may be framed in one of the circumstances below:

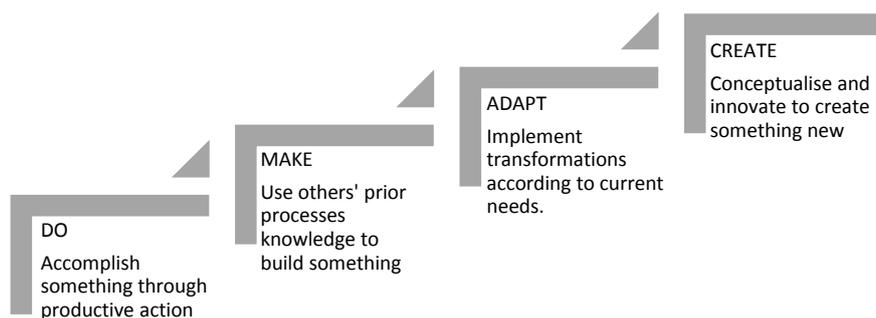
- Goals, materials and processes are known; skills and tools are available.
- Goals, materials and processes are known; skills and tools are unavailable.

- Goals are known, but material and processes (and thus skills and tools needed) are yet to be defined.
- Materials are known, but goals and process (and thus skills and tools needed) are yet to be defined.

Besides these intrinsic factors, the upcycler also faces a range of obstacles that challenge upcycling practices by designers and architects and must be addressed throughout the process (Chick and Micklethwaite (2004). These obstacles include lack of information and unfamiliarity with the process and materials, supply and transportation issues, cost (recycling and upcycling are not always less expensive than buying new material) and certification of quality. Moreover, upcyclers need to deal with a broad group of stakeholders that includes clients and suppliers (Pereira, 2008).

## Upcycler categories

The upcycler utilises creativity and develops an aptitude for recognising and dealing with the set of conditions previously described. The design is favourable when goals, materials, processes skills and tools are within the domain of the practitioner. Creativity, however, is experienced and externalised asymmetrically across different profiles. In recognition of this variance, Sanders and Stappers (2012) identified four levels of everyday creativity that can be used to categorise the innovative degree of intervention among upcyclers. As shown in Figure 2.8, these categories include doing, adapting, making and creating.



*Figure 2.8.* Creativity levels. Adapted from Sanders and Stappers (2012).

In an interesting effort to establish the differences among those identified creative levels, López (2014) compared how people with various creativity aptitudes perform different tasks, such as cooking, playing music and developing designs. At one end of the spectrum, a doer might buy an already made meal when dealing with cooking, whereas a creator might invent a recipe. One who makes or adapts might either follow instructional tools

(e.g. recipe books) or improvise with food available in the kitchen, respectively. Equally, less creative persons may be restricted to listening to music, whereas moderately creative individuals may play by following music sheets or improvising, and the creator will compose a melody. The same is true in design; however, the complexity and variants that influence the output differ from practice to practice.

Upcycling, workmanship or craftsmanship, bricolage and DIY include external factors apart from the practitioner, but participants' profiles and the essential drivers for their attitudes will determine the very start of the process. Although Atkinson (2006) recognised that the efforts to classify DIY activity are sometimes constrained by other elements listed previously as design variables, he was assertive in categorising the DIY individual. Atkinson's (2006) proposal is also suitable to classify the upcycler as follows:

- Pro-active practitioner: Actions are motivated by personal pleasure or financial prospects with substantial elements of self-directed and creative design input, that involve skilled manipulation of raw materials or original combinations of existing components.
- Reactive practitioner: Craft and building activities are supported by kits, templates or patterns that require an assemblage of predetermined components. Motivation ranges from hobby (personal pleasure) to financial gain.
- Essential practitioner: Most activities are directed towards maintenance and driven by economic requirements or unavailability of qualified labour. Actions frequently involve assessment of instructional means and may also be imaginative and personally rewarding.
- Lifestyle practitioner: Improvements and construction activities accomplished are performed as emulation or conspicuous consumption and are determined by choice rather than need. Professional guidance or design advice may be included.

This context provides an understanding of upcyclers' general behaviour, capabilities and motivations, which is pertinent to represent features of the activity and its practitioners. Although designers and architects have developed their own strategies for ideation and gaining further knowledge to deal with design concepts, developments and materialisation, they may share considerable characteristics and interests with upcycle enthusiasts.

## 2.5 Rematerial-Oriented Design Framework

This framework introduces terms, definitions and expressions developed throughout the investigation. This section focuses on the relation of the process with traditional design and the relevant aspects that characterise the ROD product compared to conventional design products. Additionally, the main stages of the process and the important role of materiality in the process of upcycling are contextualised.

Rematerial is the generic term adopted in this work to reference existing materials, objects, elements and structures that may potentially be upcycled to new and productive uses. Although the term includes, but it is not limited to, building materials resulting from leftovers or demolitions, it more generally encompasses everything that is initially considered waste, trash, found, forgotten or discarded material from some point of view. Creative and resourceful minds see an opportunity for these materials. At this moment, the discovery stage of ROD starts, and the resource becomes rematerial. Designers envisage the remaining life of the material and believe they may be able to recover its intrinsic beauty and promising functionality by performing material re-contextualization.

The decision between rematerialisation, or saving for later, or discarding, starts when material is discovered, but happens mostly in the definition phase. This definition process is aware when the designer knows clearly what to take in consideration and how to document his choices; effective when decisions are informed and assured; and efficient once saving time and unnecessary resources with unfeasibly propositions is considered.

Material or rematerial re-contextualization is a deeper definition for upcycling, and the expression also was adopted within the research. This term stands for the repositioning of wasted resources from their current situation to an improved context. The process may include no, mild or radical material transformation and is concluded after the creation of upcycled goods.

Rematerial-oriented design is the design process driven by architectural upcycling or material re-contextualization directed towards architectural or interior architectural purposes. ROD occurs on different scales. A pet bottle may become a lamp on the scale of interior architecture. Old refrigerators may be turned into vending bars. In an urban setting, an outdated aeroplane might become an interactive pathway at an urban park.

There are three categories of ROD: intuitive, reflective and skilful. This thesis proposes a fourth category called *conscious rematerial-oriented design*. Those categories are described as follows:

- Intuitive ROD is a practice accomplished intuitively with little or no formal design experience or knowledge. It is the approach adopted by beginners, and anyone may do it.
- Reflective ROD is carried out by designers or architects with experience in the architectural field. They understand the design process and have strategies to complete it. However, their know-how relating to ROD is limited because they only perform it casually.
- Skilful ROD is the activity attributed to those designers who accomplish ROD routinely within their practices. They have trained eyes for discovering materials, spatial visualisation capabilities for envisaging opportunities and expertise in the process of re-contextualization.
- Conscious ROD incorporates process improvement through awareness of constants and continuous modelling of variables directed to guide appropriate design decisions to enhance the chances of successful outcomes. The use of an information management instrument – the rematerial information modelling (REMIM) tool – is intended to enable designers with any level of expertise to perform ROD with increased effectiveness and efficacy.

The final objective of ROD is to re-contextualise wasted resources. Nevertheless, the framework development also led to a delimitation of the primordial differences that exist between ROD and traditional architectural design despite their core aims. Those variances include design problem positioning, the motivators for design, the generated product and materiality.

In the architectural process, the designer usually focuses on the solution to the design problem rather than the problem itself. This approach detaches essential attitudes of material exploration that could establish a structured path towards rematerial propositions. Thus, when resources are projected for re-contextualization, they become design problems that require thoughtful analysis, understanding and learning before the solutions can be emphasised. The process of design is the search for possible associations, and it is complete when the specifications are firmly connected with the constraints.

In conventional design, the architect conceives the elements and systems of a building and then specifies the materials and components necessary to achieve a given performance and quality. An established market already exists for the purchase of suitable materials and components.

Within ROD, the material selection stage is substituted by the identification of material with assumed characteristics and the creation of a goal for its re-contextualization. This procedure may occur within usual current processes (i.e. onsite during building construction) or may be carried out independently, in which case the starting point is guided by the availability of materials or goods.

Like material selection drivers in the building sector, motivators for ROD vary considerably from sustainability goals to material performance, cost and personal preferences, among other reasons. The remarkable factors that distinguish both are determinant for the decision to progress with upcycling. Commonly, encouragement to upcycle comes from the designer’s passion for framing the past inside the present, the challenge of solving design problems and the uniqueness of each design product, whether or not it is associated social or educational profiles, histories or emotions. Table 2.1 illustrates the most common differences between ROD and conventional design products. However, ROD products may hold conventional products’ characteristics and vice versa.

Table 2.1

*Comparison of ROD and Conventional Products*

<b>ROD Product</b>	<b>Conventional Product</b>
Intangible value	Material value
Crafted	Industrialized
Customised	Mass-produced
Unique	Standardised
Manufacturing involved	Manufacturing detached
Emotional	Unemotional
Low technology demands	Technological
Labour-consuming	Labour-saving
Time-consuming	Time-saving

This study considers ROD to occur in two main stages – goal construction and materialisation – which can be subdivided into four basic moments: discover, define, develop and deliver, conforming to the double-diamond structure depicted in Figure 2.4.

The main stages of ROD are similar to those of conventional design. However, the approach to materiality distinguishes one from another. Here, this approach is denominated *rematerial interaction*.

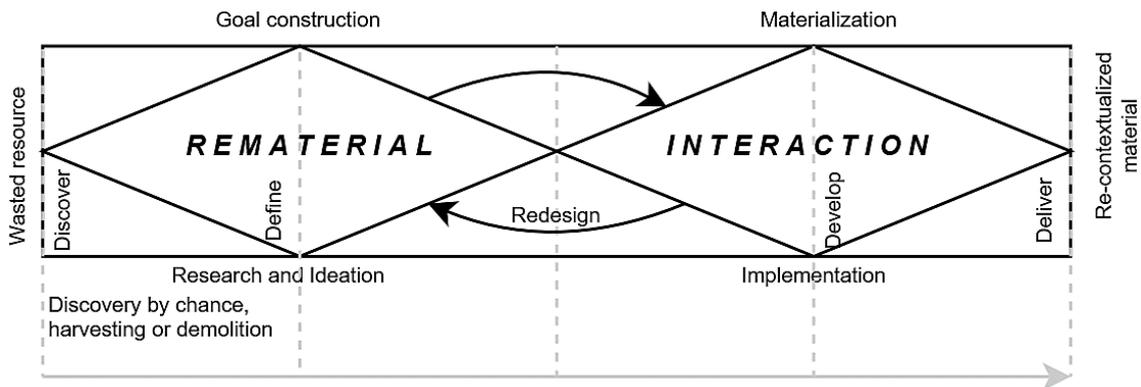


Figure 2.9. Rematerial-oriented design stages.

*Rematerial interactions* performed by designers with different levels of knowledge and experience are further investigated in the second part of the thesis, where the four stages of ROD are also examined separately.

## 2.6 Summary

This chapter aimed to provide an understanding of the dimensions related to rematerial-oriented design and upcycling, examining concepts and fundamental theories of design problem-solving, knowledge and materiality. It contextualised the framework for ROD and laid the groundwork for the theoretical problematic and empirical data collection described in the next chapters.

# Chapter 3 Methods

## 3.1 Introduction

This chapter describes how the design research methodology (DRM) proposed by Blessing and Chakrabarti (2009) is applied to achieve the objectives of the study. Using the theories, processes and methods of design identified from the literature and the link between projects and practice, this chapter details the goals, participants, materials and procedures applied in complementary projects containing different design approaches to explore rematerial interaction. The projects looked at designers' processes of thinking, designing and making in ROD.

This investigation is informed by concepts from design research and is "*tied to practice and driven by its needs*" (Roth, 1999, p.20). More specifically, the present study is based on a belief that designing and making without academic reflection upon the process is not research. According to Cross (2001), designers deal with an artificial world of artefacts, but design knowledge relates to this world and the means of contributing to the creation and maintenance of that world. This knowledge is inherent to the activity of designing and can be gained through engaging in and reflecting on that activity; copying from, re-using or varying aspects of existing artefacts; using and reflecting on the use of those artefacts; or seeking instruction about those artefacts (Cross, 2001).

The key aspect of the methodology is to formalise the awareness and conceptualization of the process to facilitate the incorporation of existing elements into emerging (and future) architectural design proposals. Given the state of art of the topic, the theories, data and developing ideas are explored in parallel during the investigation. Thus, the literature review accompanied the construction of concepts, which were refined throughout the course of this investigation to integrate and align data collection and empirical analysis.

The DRM proposed by Blessing and Chakrabarti (2009) was created to support academics in recognising research areas and projects and selecting appropriate study methods to address enquiries. The DRM can be used to systematise the methods, help the researcher establish design issues for investigation and provide guidance on how to integrate the studies conducted.

The set of methods used for the first project was depurated throughout the experiment and guided the refinement of the methods for the following steps. In general, the first

project related to a protocol analysis of rematerial design tasks accomplished by experienced designers, and it was named Reflective Rematerial Interaction. The second project, Intuitive Rematerial Interaction, recounted data produced by novice designers during a studio session for designing and building structures made from unutilised and uneven material that is described further in later sections. Relevant information generated from the first and second projects was validated and completed through a coding web generated from semi-structured interviews with designers and architects with expertise in dealing with rematerial. This last project was identified as Skilful Rematerial Interaction.

### 3.2 Design

The DRM (Blessing & Chakrabarti, 2009) comprised three stages that could be carried out linearly or cyclically, depending on the effectiveness of the means for each stage in providing the expected outcome (see Figure 3.1).

<i>Stages</i>	<i>Basic Means</i>	<i>Specific Means</i>	<i>Methods</i>	<i>Main Outcomes</i>
Research Clarification	RC Literature Review	Revision Design materiality and ROD state of art	Gap in materiality and ROD information	Goals
Descriptive Study I	DS-I Empirical data analysis	Projects 1, 2 and 3	Find factors to address and information to improve ROD	Understanding
Prescriptive Study	PS Assumption Experience Synthesis	REMIM prototype	Connect information / REMIM	Support

Figure 3.1. Basic DRM framework adopted for the study, including stages, means and deliverables. (Adapted from Blessing & Chakrabarti, 2009, p. 15).

The first stage was the research clarification (RC), which was undertaken to find evidence or indications to support assumptions used to formulate the research goal. The RC occurred continuously to adjust the theoretical framework in accordance with the findings (see Chapter 1 and 2).

The descriptive study (DS), part 2 of the thesis, was carried out to obtain a better understanding of the existing problem before moving on to the next stage and was used to start developing support to address relevant factors. Because insufficient evidence was found in the literature to clearly determine the current situation, three projects were completed as described in the following sections.

Throughout the next stage, the prescriptive study (PS), within the third part of the document, enhanced understanding of the existing situation was used to correct and elaborate on the initial description of the desired situation. This description represented a preliminary picture for considering how factors in the existing situation might lead to

situational improvements. Here, the results of the descriptive study enabled the construction of a reference model (which encompassed the existing situation) and an impact model, termed *conscious rematerial interaction*, which addressed the intended situation. This stage also provided contextualization of the rematerial information modelling tool. Figure 3.2 details the framework of the applied DRM.

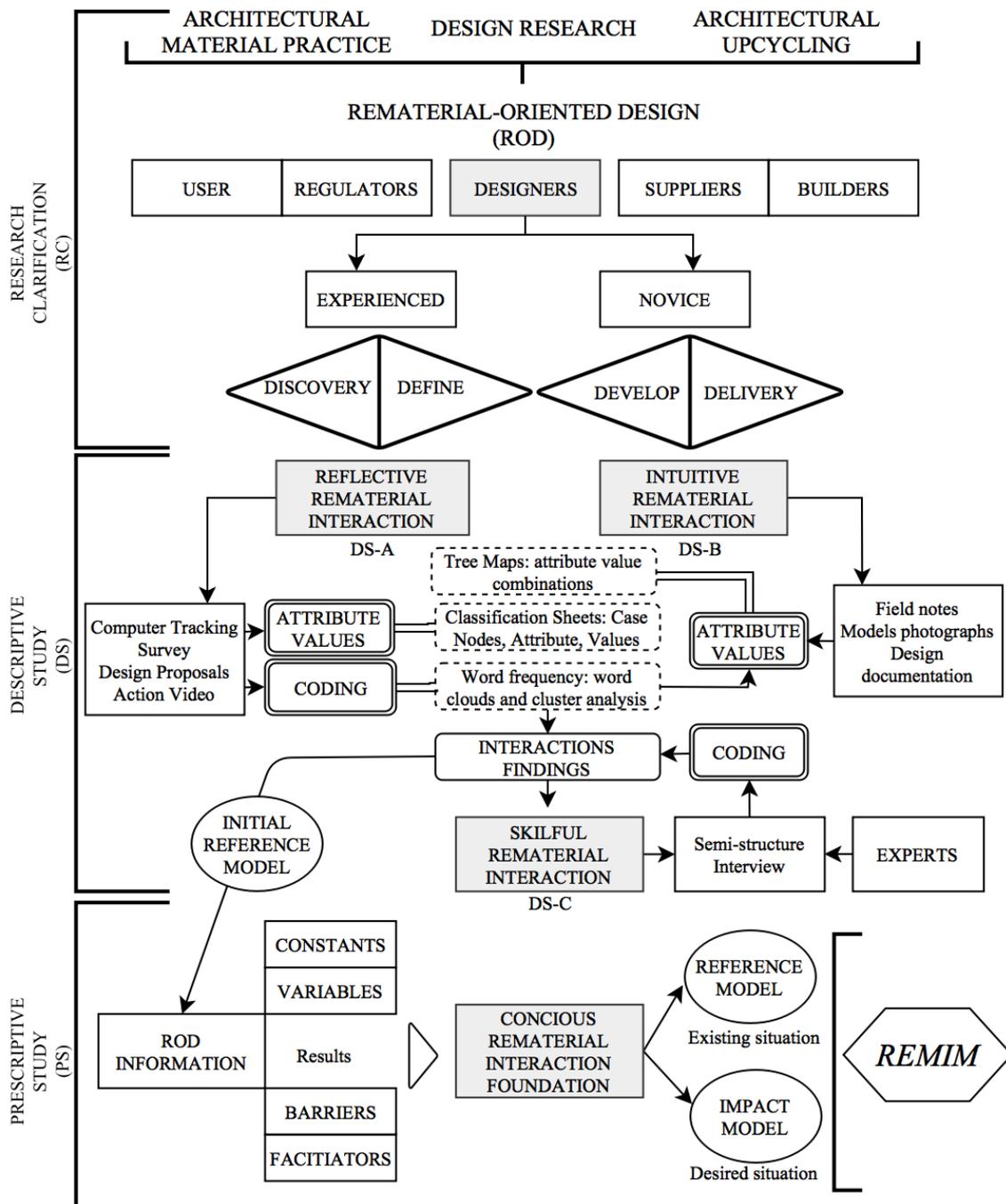


Figure 3.2. Detailed DRM adopted for the thesis.

Research clarification is located at the top of Figure 3.2 and illustrates the thematic approach and the interaction of the designer with materiality as the pivot point of the

entire investigation despite the other agents involved in the ROD process. RC contextualised the double diamond as a simplistic model adopted to thematize the main activities of design practice. In the current framework, the four activity clusters (discover, define, develop and deliver) were examined two by two. Discovery and definition relate to experienced designers, whereas development and delivery refer to novice designers.

The bottom of Figure 3.2 details how the findings from the projects were arranged to provide information to achieve the objectives of the thesis. This portion of the diagram shows how knowledge generated from the interactions was employed to develop an understanding of the existing scenario and the requirements for the desired scenario, which allowed for later development of a conceptual model for process improvement. The prescriptive study will be described in Chapter 7.

The descriptive study is embodied in the middle of the diagram and represents the three associated projects: reflective, intuitive and skilful rematerial interactions. This section of Figure 3.2 gives a general view of the type of data collected for these studies and the means employed for structuring, visualising and analysing that data. In this research stage, most of those means were supported by NVivo, a computer-assisted qualitative data analysis software. The DS is the core of the next part of the thesis, and the methods, terminologies and NVivo employment are detailed in the next sections.

### 3.3 Descriptive Study

The DS comprised three different projects that aimed to explore designers' activities related re-contextualization of discarded goods. As previously stated, the projects were named Reflective Rematerial Interaction (DS-A), Intuitive Rematerial Interaction (DS-B) Skilful Rematerial Interaction (DS-C). The main objectives of the three projects were to elicit empirical information on the application of knowledge generated during rematerial interactions and, thereby, establish the determinants for formal process improvements to support rematerial interactions. Awareness of the procedures executed by designers of different levels and skills was intended to support the identification of strategic strengths, consolidated habits, weaknesses and gaps of ROD intuitively and reflectively performed. Thus, it was essential to identify and access critical items to improve process efficiency.

### 3.3.1 Sample size

The projects included different sample sizes of architects and designers with distinct profiles. Qualitative research usually requires smaller sample sizes than do quantitative studies, but researchers must have a sufficient number of participants to respond most insights previously elaborated.

Glaser and Strauss (1967) endorsed the concept of sample size saturation for appropriate qualitative analysis. The well-known guidelines for determining sample size in qualitative studies recommend anywhere from five to more than 50 participants, however, and the literature does not specify rules for accurate calculation. Morse (1994) recommended that between 30 and 50 consultations were needed for grounded theory studies and at least six for phenomenological studies, whereas Creswell (1998) suggested 20–30 consultations or five to 25. Bertaux (1981) stated that 15 participants are the minimum acceptable sample for all qualitative research.

The current study adopted the position of Patton (1990) and Holloway (2013), wherein the qualitative sample size may be determined depending on the research profile, the research question, and the material and time resources available. This approach is supported by a Morse (2000), who argued that *“the number of participants required in a study is one area in which it is clear that too many factors are involved, and conditions of each study vary too greatly to produce tight recommendations”* (Morse, 2000, p.5)

DS-A and DS-B comprised 10 and 31 participants, respectively, and both were small sampling units that were studied in depth. DS-C reduced the number of interviewees to two because this number was found to be enough to validate the coding structure developed through analysis of previous projects.

### 3.3.2 Protocol analysis

In design research, protocol analysis has been considered one of the most important methods to access the enigmatic cognitive abilities of designers (Cross, Christiaans, & Dorst, 1996). Traditionally, protocols refer to thinking verbalizations and successive behaviours that research subjects use while performing cognitive tasks. Protocol analysis is a psychological research method that aims to apply verbal reports as data (Ericsson & Simon, 1993).

Darke (1979) contextualised awareness of designers' mental processes as the essential research material to understand the design problem; observing sketched and written pieces is an interesting and effective means to acquire that information. In this context, protocol analysis involves an empirical, observational research method in which the protocol is a record of the time track of behaviours. From the design perspective, the application of this method often requires the incorporation of other conventional observational methods to accommodate non-verbal reports (Jiang & Yen, 2009). As exemplified by Akin (1984), design protocols commonly include the register of designers' visible behaviours, verbalizations, graphical representations and audio-visual recordings captured by cameras.

In an extensive review of protocol analysis in design research, Jiang and Yen (2009) identified that most protocols refer to design processes that started with analysis of design problems and ended with design solutions with a certain level of details. The researchers determined that a two-hour timeframe for the experiment was appropriate because the participants could maintain concentration and develop design concepts with certain details during this span of time (Jiang & Yen, 2009). Because it can be challenging to recruit professional designers, particularly renowned ones, to contribute to research projects, some authors have suggested mixed sets that evaluate both professional designers and design students.

Given its suitability for analysing design activity, protocol analysis was adopted for the first and second projects in this study. In the first project, data were obtained through rematerial design tasks performed by professional architects and designers recruited especially for the activity. The second project addressed retrospective design material produced by students in a studio learning context. Both projects are detailed within the next chapters of the thesis.

### 3.3.3 NVivo

Computer-assisted qualitative data analysis software (CAQDAS) has been considered a differential research aid for *“a more accurate and transparent picture of collected data, whilst also providing an audit of the data analysis process as a whole – something which has often been missing in accounts of qualitative research”* (Welsh, 2002).

QSR NVivo combines the administration of non-numerical unstructured data with indexing and conjecturing processes. It enables the researcher to develop themes that have

yet to be identified and allows the input of different formats of data (e.g. journal notes, video, audio, documents and media sources) to be incorporated into the analysis (Silverman, 2013). According to Kvale (1996), NVivo supports an organic approach to coding because it permits coding of patterns or categories of interest in the text as soon as they are found to keep track of emerging and developing ideas.

The use of software for supporting qualitative data analysis has been widely discussed. Some critics have stated that the programs may influence and direct researchers in pre-determined paths (Seidel, 1991), detach researchers from the data or encourage quantitative analysis of qualitative data (Barry, 1998). Software advocates, in contrast, have defended CAQDAS, arguing that it allows for a more precise and clear analysis with straightforward access to references for a reliable picture of the data (Morison & Moir, 1998; Richards & Richards, 1991; Welsh, 2002). Consistent with the developer, NVivo is not designed to favour a specific methodology; rather, it is intended to simplify common qualitative practices for organising, analysing or sharing data (QRS International, 2012).

Despite the assorted opinions on the topic, NVivo has been identified as an important instrument for structuring data from the projects and enabling a reliable and transparent visualisation of the information collected for analysis. This software simplified navigation through sources and the retrieval of information. Contrary to appearances, however, processing data through this software is not a straight way, especially for design research. The development of an appropriate methodology to answer the research questions and model the methods to fulfil the study needs within the tool demands considerable initial investigation and a clear definition of objectives.

For a further understanding of the methods developed for this study, it is relevant to present some key terms for NVivo software and explain coding as a technique for exploration of qualitative data. This sub-section, therefore, will discuss the meaning and application of nodes, coding and nodes references; classifications; attributes; values and means of data visualisation (e.g. word frequency queries, tree maps and word clouds) specifically employed in this study. NVivo offers numerous other tools and endless applications even for those few functions used in this study. The CAQDAS, therefore, enabled uncountable possibilities and may be a useful instrument to increase the efficiency and accuracy of qualitative analysis carried out manually.

Coding is an exploratory problem-solving process that represents an initial step towards the investigation and understanding of unstructured data sources. Conforming with QRS International (2012), coding is the process of labelling material by topic, theme or case. NVivo software allows researchers to gather correlated material in one place so that emerging patterns and ideas may be found. Holloway (2013) stated, however, that codes are more than labels; they are linking agents for finding patterns, which may be characterised by similarities, differences, frequencies, sequences, correspondences and causations.

In NVivo, codes are termed *nodes* and may be created hierarchically as nodes and sub-nodes or, in the terminology adopted by the program, parent nodes and child nodes. During or after the establishment of the nodes, researchers may link different formats of information to each node. This information is easily accessible, may be listed and exported and may be aggregable to its parent node's information. In this study, two types of information (or references) have been linked to the nodes.

Two sets of nodes were formed for DS-A. The first set included the coding of sources into patterns. The other set of nodes segregated participants into case nodes with groups of attributes assigned to each. This form of attribution of information to case nodes was also employed within DS-B.

Coding is a standard technique in NVivo. It is performable after diverse formats of digital data are imported into the platform and throughout the exploration of these sources. As relevant words, terms or excerpts emerge, they can be highlighted and then coded to new or existing nodes. Those coded references are accessible afterwards and may be used for directed visualisation, reflexion and enquiry.

The nodes also may be classified. Conventionally, node classifications enable the recording of information about people, places or other cases, such as demographic data about people (QRS International, 2012). In the current projects, node classifications were applied unusually to attribute individual observations and perceptions collected from the processes to respective cases.

When defining the properties of those classifications, researchers may add attributes coherent to what type of information needs to be organised from the cases. Numerous values (numerical, textual or temporal) may be linked to each attribute, but only one will be assigned at a time. Attribute values may carry descriptions and colours.

Classification sheets provide an overview of the items (attributes and values) in a particular classification. They are represented by matrices of nodes versus related attributes and filled out with designated values, as exemplified in Figure 3.3.

Case Nodes	Attributes	Values		
Protocol			A : Computer Act 0-15 min ▾	B : Computer Act 15-30 ... ▾
			C : Computer Act 30-45 ... ▾	D : Computer Act 45-60 ... ▾
1 : D (01) Protocol	Survey	web search	Idle	Text editing
2 : D (02) Protocol	Survey	web search	Digital tool	Digital tool
3 : D (03) Protocol	Survey	Text editing	Idle	Idle
4 : D (04) Protocol	Survey	Idle	Idle	Digital tool
5 : D (05) Protocol	Survey	Idle	web search	Text editing
6 : D (06) Protocol	Survey	Digital tool	Idle	web search
7 : D (07) Protocol	Survey	Idle	Idle	web search
8 : D (08) Protocol	Survey	web search	web search	web search
9 : D (09) Protocol	Survey	Text editing	Idle	web search
10 : D (10) Protocol	Survey	web search	web search	Digital tool

Figure 3.3. Node classification sheet in NVivo.

After information is input, NVivo enables the user to run queries to bring the information together (QRS International, 2012). NVivo queries may be used for different aims, such as finding identified words or phrases in sources and nodes or finding those that occur most frequently. These terms also may be related to codes such as coding query, matrix coding query, coding comparison, and compound or group query.

Because of the data arrangement adopted for this study, the information generated for analysis within the projects were visualised through the support of two NVivo tools: word frequency queries and tree maps.

The word frequency query was run in DS-A. This query enables the user to search for word occurrences in any part of a project (e.g. nodes, sources, memos). According to the user's adjustments to search locations, word lengths and number of frequent words, the query will display the same results in four formats: summary, word cloud, tree map and cluster analysis (see Figure 3.4).



the tree. The tree maps also present the option to show attribute value colours as previously defined.

### 3.4 Prescriptive Study

The prescriptive study, which comprises Part III of the thesis, complemented the framework for ROD presented in the research clarification and introduced the reference model for the current situation and the impact model, which referred to the desired situation. The framework for these models was based on the findings from the literature review and the results of descriptive studies A, B and C: intuitive, reflective and skilful rematerial interactions, respectively. The reference model outlined the base for the intended process improvements.

The impact model, termed *conscious rematerial interaction*, introduced the foundational concepts for REMIM (the rematerial information modelling tool), an information management instrument aimed to help designers become more aware, effective and efficient in ROD practice. It represents the envisioned situation and shows the assumed impact of the support to be established (Blessing & Chakrabarti, 2009) and is the outcome of the prescriptive study.

As Blessing and Chakrabarti (2009) stated, models are used in science to organise concepts. They represent something that exists but are focused on specific aspects of a given reality. Although models are not theories, they may be used to represent theories. Models may show significant relationships between concepts or attributes and thus illustrate the aspects that are the focus of the research. Figure 3.5 presents the main products of the descriptive and prescriptive studies conducted for this dissertation, which will be described in the next chapters.



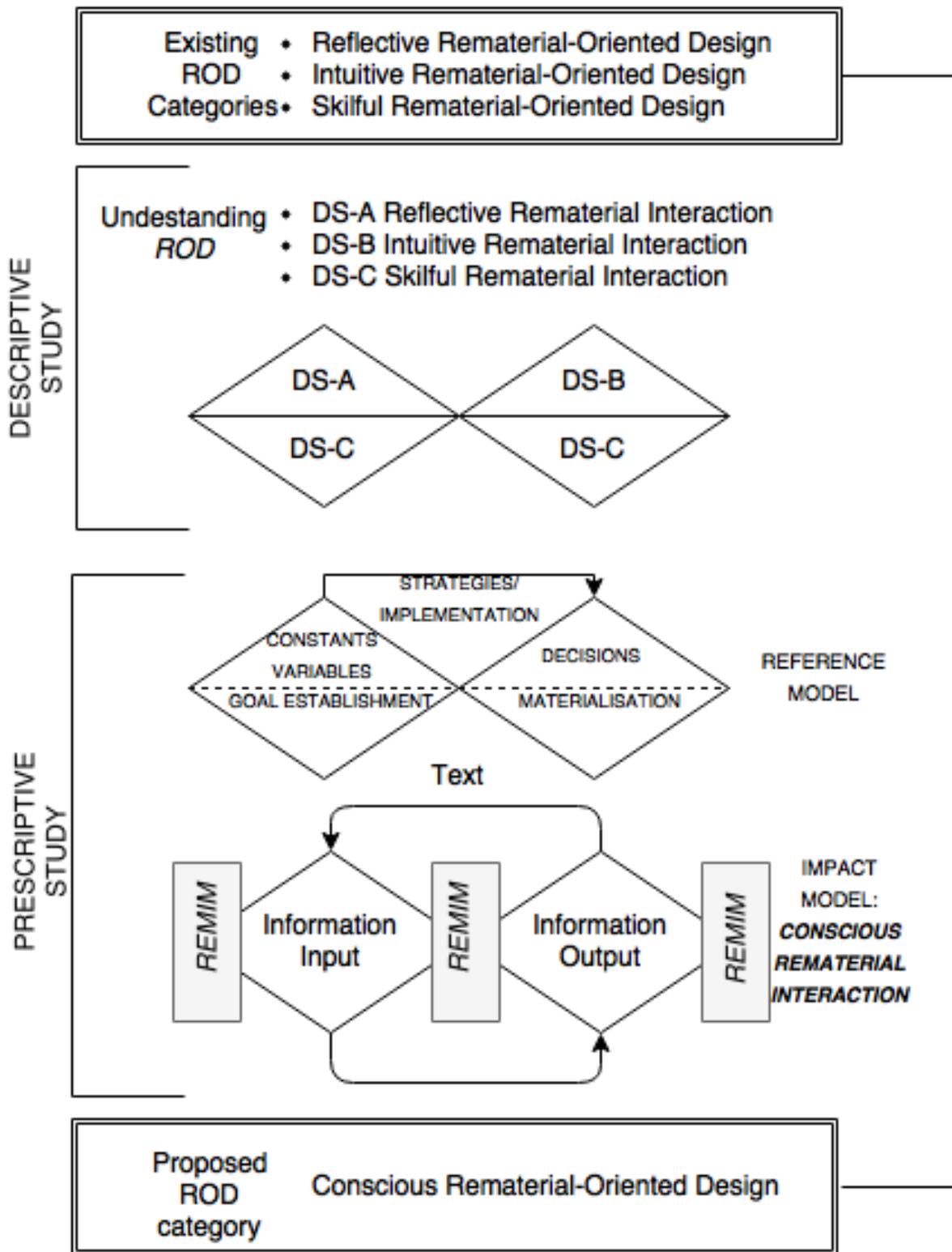


Figure 3.5. Reference model and impact model in the DRM methodology.

### 3.5 Summary

This chapter detailed the methodology, DRM, and related research stages adopted to address the research questions. It described the structure, methods and objectives of the research clarification, the construction of the theoretical background, the empirical data analysis of the descriptive study and the assumption experience synthesis through the prescriptive study.

**PART II**  
**Descriptive Study**

## PART II – Descriptive Study

*“Listen to an object long enough, and it will tell you what it wants to be next.”*

(Rodney Allen Trice)

Part II of the thesis presents the practice-based projects, patterns and perceptions that emerged about ROD and its related stages: discovery, definition, development and delivery. Data were gathered and processed with the aim to address the problems described in the first chapter of this thesis. Two central factors drove the data collection and subsequent analysis: the designer-based understanding of the ROD process and the importance of providing grounding knowledge to form the basis of a model for an improved process that is more aware, effective and efficient.

Chapter 4 describes Reflective Rematerial Interaction (DS-A), a protocol analysis focused on ROD performed by experienced designers that concentrated on the discovery and definition phases of the process. Chapter 5 presents Intuitive Rematerial Interaction (DS-B), a content analysis of visual data generated by novice designers. This section looks mainly at the development and delivery phases of ROD throughout the examination of design documentation, photos, drawings and models. Chapter 6 discusses Skilful Rematerial Interaction (DS-C), which was evaluated through semi-structured interviews with expert rematerial designers directed to confirm and enhance the information generated from the previous projects.

## Chapter 4 Reflective Rematerial Interaction (DS-A)

DS-A comprised a protocol analysis and looked at the discovery and definition phases of ROD. Participating architects and designers were asked to complete a questionnaire and accomplish a design task. Participants had between 30 minutes and 3 hours to complete these tasks, and they could use their laptops and any drawing or modelling tools they wished. They were even permitted to leave the room. Their computer activities were tracked, and their actions and movements were recorded. Computer activities, actions and the documents generated during the experiment were analysed to identify how the designers reasoned in the early stages of rematerial-oriented design.

### 4.1 Objectives

The methods applied for this project aimed to detect contemporary design tactics and tools adopted to generate and materialise ideas for upcycling and, consequently, to perform ROD. This represented the initial step towards comprehending design thinking in ROD during discovery and definition. Specifically, the objectives were as follows:

- relate design strategies with design decisions;
- diagnose contemporary digital or manual methods for elaborating and presenting initial ideas associated with ROD tasks;
- identify means and depth of collection and learning of material information in early stages of design development; and
- recognise familiarity with and approaches to materiality.

### 4.2 Participants

The participants for this project included 10 architects with backgrounds in the field. Participants were required to have a minimum of 3 years of experience and be able to dedicate up to four hours for the experiment. Recruitment occurred through official letters sent to social media profiles (LinkedIn) and by word of mouth. Among the professionals who agreed to participate, five were architects who had graduated in Australia; one had studied in India; three were architects and urban planners who had graduated in Brazil; and one had acquired a master's degree in landscape architecture in Poland. Their professional experience ranged from 3 years to 40 years.

When describing their familiarity with upcycling, half declared that they upcycled for personal purposes but not for professional purposes. Only one was not familiar with the concept of upcycling, and another reported being bad at it. Two participants declared a tendency to give up easily when trying a project.

## 4.3 Materials

### ESURV

The website eSurv (<http://www.esurv.org>) is a platform for the elaboration and release of surveys. It was employed to support the development of the questionnaire to be completed by the participants during the protocol. This questionnaire contained two design tasks and some other questions about the designers' backgrounds. The survey can be found in Appendix A.

### ACTIVTRAK

ActivTrak (Birch Grove, Version 2015) is a cloud-based monitoring software used for tracking web and application usage from workstations containing an invisible agent. All relevant information acquired is shown in real-time on a dashboard. This platform allows data to be stored and exported in spreadsheet format. This application was installed under agreement on the computers used by the participants during the experiment, and it collected title bars, URLs, software usage and regular screenshots throughout the time they worked to solve the design task.

### DRAFTING AND MODELLING TOOLS

Diverse tools for hand drawing and physical modelling were supplied for each designer to use during the protocol. These tools were spread on the table and were readily available; they were shown to the participants before the commencement of the project. The range of materials included paper (of different thicknesses and colours), cardboard, scissors, glue, pencils and pens, markers, scalers, squares, cotton fabric, pipe cleaners, stick tape, wooden sticks and modelling clay.

### ATHOME CAMERA

AtHome Camera (iChano Incorporation, Version V3.5.0) is a video monitoring application that allows real-time recording from mobile devices to be sent to computer

stations. It was used in conjunction with an iPhone 4S to film the movements of contributors while designing. These tools tracked whether designers worked on computers or manually, when they took breaks and how they manipulated materials. They were watched remotely and the software also provided live communication. Digital videos were captured and regularly saved (every 10 minutes) to minimise loss in case of a software crash or corrupted video files.

## PLASTIC LIDS

The participants were provided with a box of plastic lids. There were 250–300 circular lids of different colours, sizes, textures and finishing. The lids could be touched, manipulated and applied throughout the design development because one of the tasks included creating a proposal from this material.

## NVIVO

NVivo10 (Granta Design, 2017) is computer-assisted qualitative data analysis software (CAQDAS). As stated before, it was used in these projects to aid in data management, coding, analysis and data visualisation.

## 4.4 Procedures

The project aimed to examine the strategies that architects and designers adopted to make design decisions involving rematerial. Because digital development for design has evolved constantly, the path architectural professionals take to crystallise early ideas and solve different design problems must be equally dynamic.

Thus, this project involved an online survey that asked participants to complete two separate design tasks. The timeframe for these tasks ranged from 30 minutes to 3 hours to ensure that the focus was on the early stages of the design process (discovery and definition). The intention was not that participants would complete the exercise fully with precise and detailed responses but rather that they could spend their time learning about the material they were going to deal with, developing initial insights and searching for information as needed to develop these ideas better.

The questionnaire was constructed based on the considerations of the different emphases of the investigation. The first part asked participants to provide a brief description of their professional backgrounds (qualification, location and year of completion); the second was

a multiple-choice question about how familiar the person was with upcycling. This portion of the questionnaire was designed to register the diversity of the participants.

The third and fourth questions were central to the task at hand. Question three asked participants to develop a design proposal, containing as many details as possible, to use plastic lids (which were provided). Question 4 asked participants to develop a proposal for using a pile of rails. Attached to this question was an Australian standard specification sheet listing the properties of the material and the drawing of a section with dimensions.

Proposals used two very different types of materials – plastic lids and rails. The first were colourful, light, malleable, flexible, easy to melt and pierce, and general the inverse of the steel rails. These materials were chosen for the following reasons:

- to encourage variety of work scales,
- to encourage the search for and learning about information on different materials,
- to stimulate diverse design skills, and
- to instigate physical manipulation of the accessible material and mental (or digital) exploration of the unapproachable.

The recruited participants completed the questionnaires at a time of their convenience, and the maximum number of attendees at any given experiment session was two. Once all the material was ready and the participants were prepared, the following steps were carried out:

4. Check with the participant to see whether he or she intended to use a laptop (if not, there was always one available for lending).
5. Provide ethics documentation and links for the survey.
6. Install tracking software on the participant's laptop (tracking information was sent in real time directly via an online dashboard monitored by the researcher).
7. Provide the participant with the questionnaire and a box containing assorted drawing and modelling tools.
8. Provide a means of immediate communication in case the participant needed to contact the researcher throughout the task or after completion.
9. Position and start the camera.
10. Allow the participant up to 3 hours to complete the task.
11. Uninstall ActivTrak from the participant's laptop.

12. Back up relevant files (see Figure 4.1) and digitalise the drawings and models produced.

The files collected from the participants were input and organised in NVivo under the structure shown in Figure 4.1.

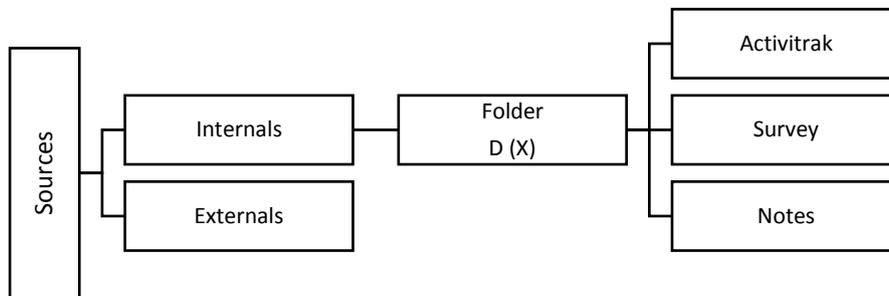


Figure 4.1. Organisation of participant files.

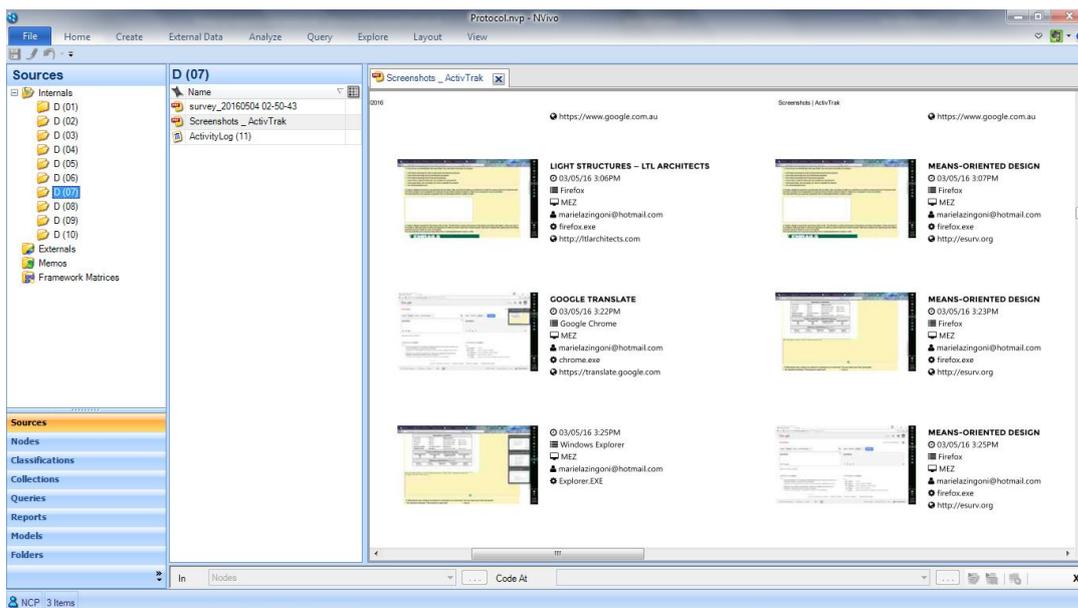


Figure 4.2. Sample of one subfolder from “Sources” in NVivo

“Sources” is the software file where research materials, including photos, datasets, documents, PDFs, audio, video and memos, can be stored. In this project, only the “Internals” sector was used. One folder was created for each participant and named D (X) with X ranging from 1 to 10. Each folder contained data relevant to the study. Redundant information not relevant for coding was not uploaded into NVivo because this would have caused the program to slow down. An average of three files was added to each folder,

including an activity log generated in ActivTrak, a PDF with computer activity screenshots and a PDF of the completed survey. Most of these documents did not have notes. The researcher opted to access photographs and videos from external software because of the large volume of recorded material and the size of the files.

The analysis of the project was carried out from the development of two sets of nodes, which were separated into folders: Data Details and Participants (Figures 4.3 and 4.4). These names were also applied to the two cores of the investigation.

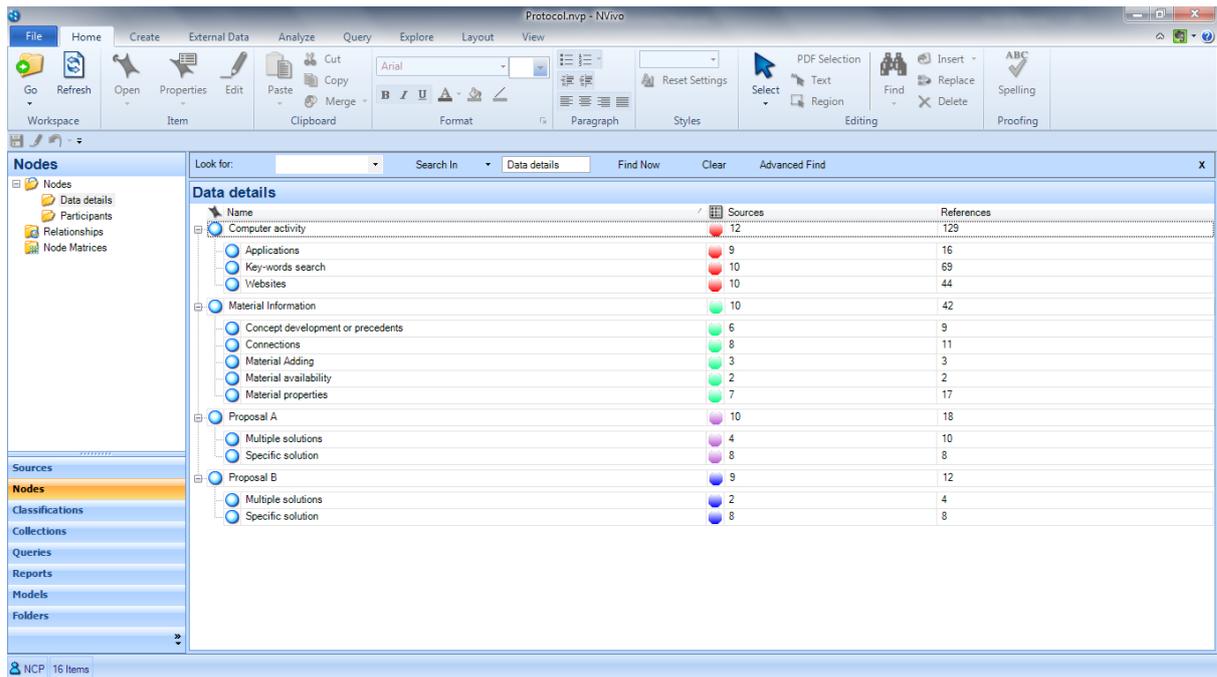


Figure 4.3. Node structure: Data details.

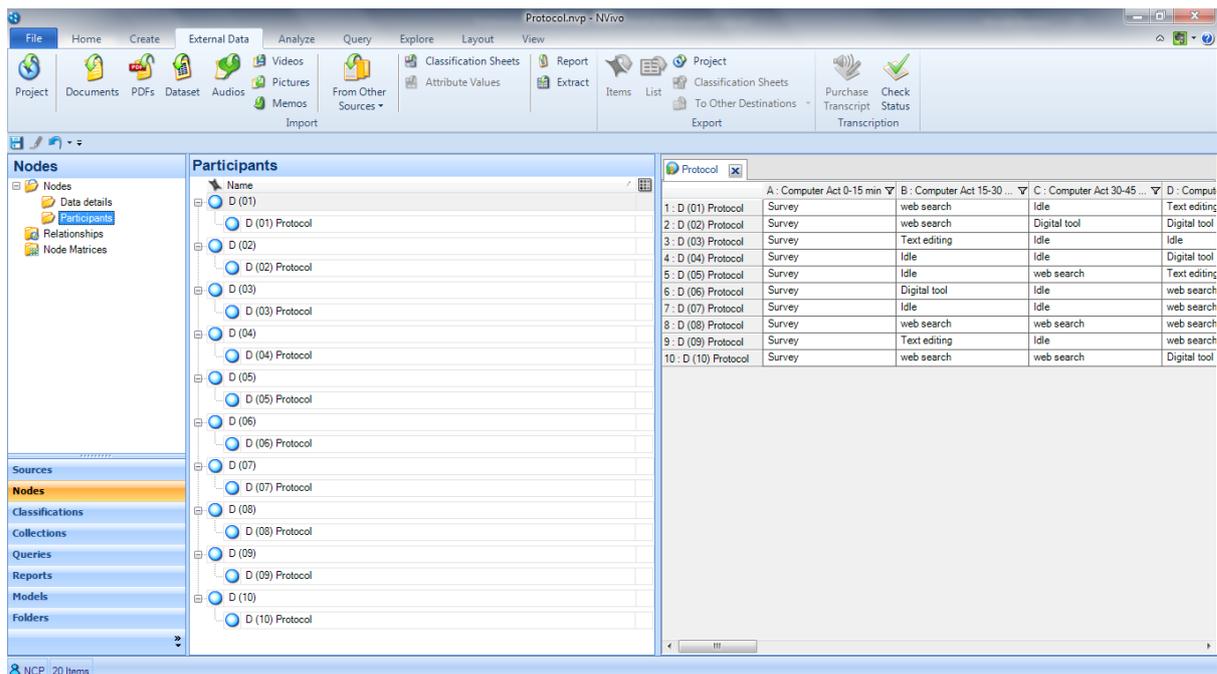


Figure 4.4. Node structure: Participants.

In the participant nodes, the cases were arranged to enable a distinct visualisation of the individual descriptions of the architects recruited based on their activities during the experiment. Ten nodes named D (X), with X varying from 1 to 10, were created and classified separately in consonance with the description of the participants. For each parent node, a child node named D (X) Protocol was created as well, and those nodes were attributed values for their design activities.

Following the structuring of the two case nodes in NVivo, the analysis of each set of nodes, Participants and Data Details, was also considered in two parts. The first described the profiles of the participants, generalised their proposals and determined the main specific activities performed by each designer at 15-minute intervals throughout the duration of the experiment. The second looked at the experiment with a focus on the characteristics of the material approaches developed in the proposals and the specific tools accessed during design reasoning.

#### 4.4.1 Case nodes: Participants

This set of nodes was designed to visualise the 10 cases individually. It was the base for the development of two classifications of the nodes. Because a single node may receive only one classification in NVivo, the case nodes were segregated into parent nodes (to attribute description) and child nodes (to attribute data from the protocol) for each case to allow the data to be visualised. Each classification enabled the creation of numerous attributes with non-numerical values.

Table 4.1

*Attributes and Non-Numerical Values from Node Classification “Description”*

NODE CLASSIFICATION: DESCRIPTION	
ATTRIBUTES	OPTIONS OF VALUES TO BE ASSIGNED
Qualification	<i>Architect/Arch. and Urban Planner/Landscape Architect</i>
Country (of qualification)	<i>X</i>
Year obtained (of qualification)	<i>X</i>
Upcycle practice	<i>Field/Home/Flairless/Quitter/Unfamiliar</i>
Lids proposal description	<i>Text/Drawings/Virtual Model/Physical Model/Images</i>
Rails proposal description	<i>Text/Drawings/Virtual Model/Physical Model/Images</i>
Obstacles foreseen	<i>1/2/3/4/5/6/7/8/9/10/11/12</i>

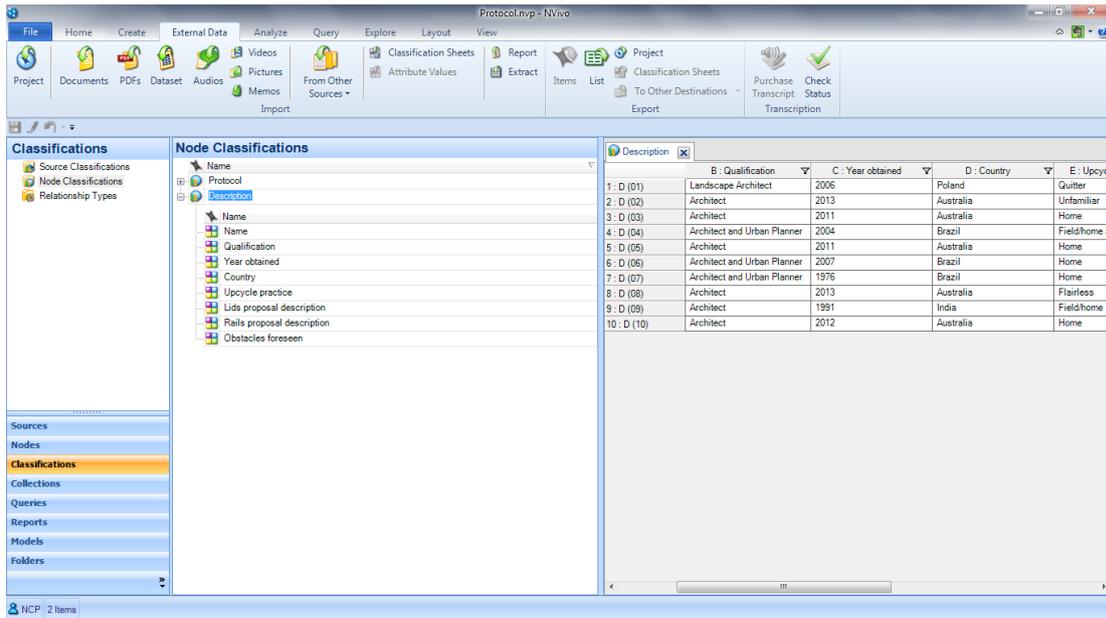


Figure 4.5. Classifications, node classifications, description and attributes

Table 4.2

Attributes and Non-Numerical Values from Node Classification “Protocol”

NODE CLASSIFICATION: PROTOCOL			
ATTRIBUTES	VALUES	ATTRIBUTES	VALUES
Computer Act 0–15 min	<i>Survey</i>	Actions 0–15 min	<i>Reading</i>
Computer Act 15–30 min		Actions 15–30 min	
Computer Act 30–45 min		Actions 30–45 min	
Computer Act 45–60 min		Actions 45–60 min	
Computer Act 0–15 min (2nd hour)	<i>Web search</i>	Actions 0–15 min (2nd hour)	<i>On computer</i>
Computer Act 15–30 min (2nd hour)	<i>Text editing</i>	Actions 15–30 min (2nd hour)	<i>Modelling</i>
Computer Act 30–45 min (2nd hour)	<i>Idle</i>	Actions 30–45 min (2nd hour)	<i>Sketching/drawing</i>
Computer Act 45–60 min (2nd hour)	<i>Digital tool</i>	Actions 45–60 min (2nd hour)	<i>Pause</i>
Computer Act 0–15 min (3rd hour)	<i>Not applicable</i>	Actions 0–15 min (3rd hour)	<i>Not applicable</i>
Computer Act 15–30 min (3rd hour)		Actions 15–30 min (3rd hour)	
Computer Act 30–45 min (3rd hour)		Actions 30–45 min (3rd hour)	
Computer Act 45–60 min (3rd hour)		Actions 45–60 min (3rd hour)	

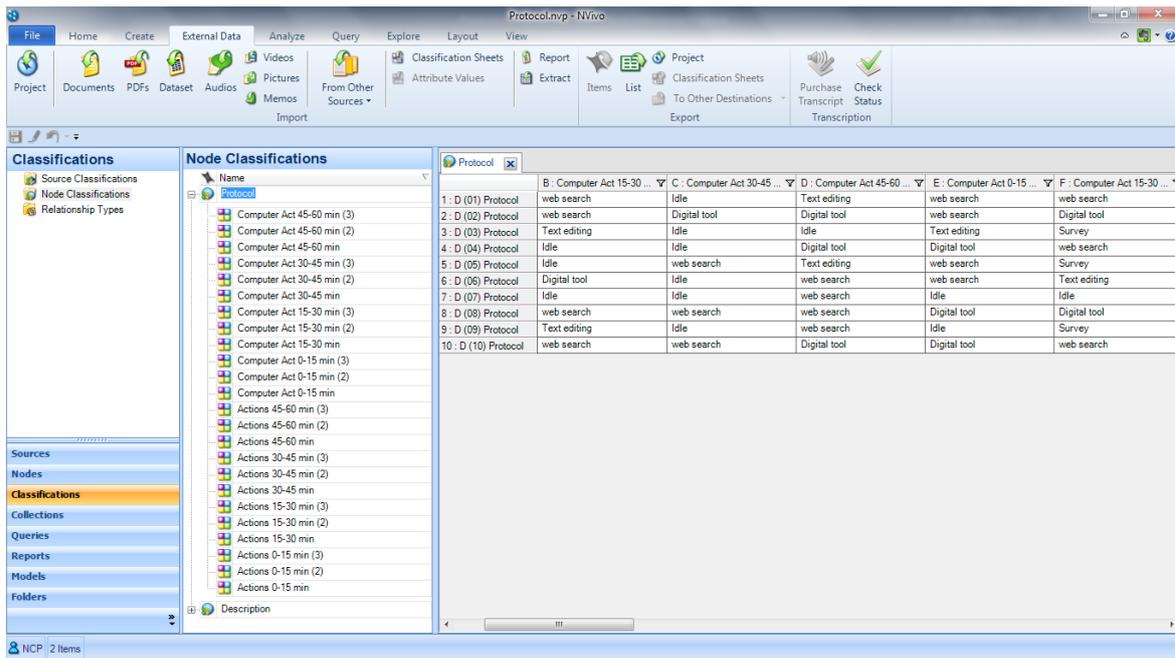


Figure 4.6. Classifications, node classifications, protocol and attributes.

Survey PDF files were used to retrieve information to attribute values to items related to the classification of “Description”. ActivTrak PDFs (screenshots and activity logs) allowed “Computer Act” attributes to be valued, whereas video files (MP4) served as the basis for “Actions” attributes within the classification “Protocol” (see Figure 4.7). This data structure enabled the researcher to generate two classification sheets in NVivo to visualise and consider facts for analysis. The classifications sheets (in Appendix A) were exported to Microsoft Excel, where similar values received similar colours.

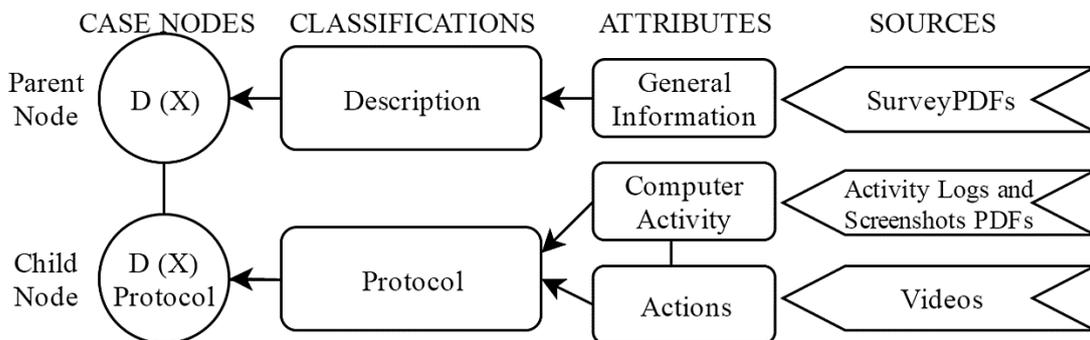


Figure 4.7. Sources of information for attributes and classifications.

## 4.4.2 Case nodes: Data Detail

The second set of nodes analysed in this project were named “Data Detail”. This analysis explored the sources (surveys, activity logs, screenshots and notes) added to NVivo to find and code relevant words, terms and definitions used by the participants to describe their proposals. These sources were generated by the automated tools applied for the collection of activity information throughout the experiment. Four parent nodes were created: Computer Activity, Material Information, Proposal A and Proposal B (see table 4.3). As stated previously, it is possible to aggregate coding from child nodes in NVivo; thus, the parent nodes enable the visualisation of the general picture (by showing coding from all related child nodes) for a theme or topic, and the child nodes capture coding from specific subthemes.

Table 4.3

*Nodes and Child Nodes from Node Classification “Data Detail”*

Parent Nodes	Computer Activity	Material Information	Proposal A	Proposal B
Child Nodes	<i>Applications</i> <i>Keyword search</i> <i>Websites</i>	<i>Connections</i> <i>Material addition</i> <i>Material availability</i> <i>Material properties</i> <i>Concept development/ precedents</i>	<i>Multiple solutions</i> <i>Single solution</i>	<i>Multiple solutions</i> <i>Single solution</i>

After the sources were coded, the reference views were extracted for each child node individually and for the set of nodes as a whole; furthermore, the researcher also ran and exported word frequency queries. The word queries were materialised through word clouds, which presented a picture of the main tools applied strategically during the early stages of design, including online, and the principal considerations of materiality within the initial ROD process. The word clouds could be read in conjunction with the references attached to each node.

## 4.5 Results

The following description summarises the participants’ design activities during the protocol and the findings from the material coded. Data were retrieved from the

classification sheets in NVivo based on computer activities tracked by ActivTrak and actions from videos as well as from word queries for coding references. The full set of classification sheets, word clouds, node references, and observation and analysis tables are included in Appendix A. For isolating associations with process awareness, effectiveness and efficiency (according to the objectives of the thesis), relevant considerations were marked with the affecting factor(s) inside brackets.

Data visualisation made noticeable the most common strategies applied to document and describe the proposals for the lids. They included text, drawings, and digital and physical models. Only one participant did not include any text relating to the proposals; two used digital models and web images instead of manual drawings or sketches. Digital tools were used for visualisation, modelling and manipulation, especially for the projects related to the rails, whereas the lids primarily were physically manipulated at the beginning of the exercise.

In the first hour of the protocol, there was an intercalation of activities between goal construction (building of ideas and research of precedents) and materialisation. Participants intensely interpolated web searches with sketches and drawings to define and develop ideas on paper. Only two participants continuously executed one predominant activity during this time. This first hour also was characterised by material manipulation, experimentation and physical modelling.

Half of the participants completed the task within the second hour. Four participants did some physical modelling using the material provided at some stage, and only two created no sketches or drawings during the whole experiment.

The materialisation of ideas characterised the third hour. Although the remaining participants (5 out of 10) predominantly worked on their computers, web searches were rare or null (there was only one occurrence among all remaining participants). Registered activities included digital tools usage and text editing to finalise the descriptions of the proposals created in the survey.

The most used application was Microsoft Word, followed by ARCHICAD, Rhinoceros and Sketchup (which received equal usage). Autodesk 3D Max, Adobe, Evernote and Photoshop were used to a less extent. It was interesting to note, however, that some applications for tridimensional computer graphics and CAD – namely, Rhinoceros, ARCHICAD and Sketchup – were applied in such a short amount of time.

The word most searched on the web was “plastic”, which did not always appear in conjunction with the word “lids”, the second most frequently searched term. The most commonly searched words related to original elements (“plastic”, “lids”, “rail”, “bottle”, “train” and “caps”) and were followed by process titles (“recycle” or “recycled”, “ways”, “upcycling”). The words that appeared at least twice were mixed (e.g. “railroad”, “furniture”, “made”, “reuse”, “design” and “ideas”).

Google was by far the most frequently used search engine. All participants employed this web search tool at least once, and Google was the guide for all other websites. The next most popular websites were Pinterest, forums, YouTube, Yahoo! Answers, Wikipedia and other varieties (for terms such as “care”, “living”, “translate” and “science”).

Word frequency was not an appropriate channel for analysing the node related to concept development and precedents. This node highlighted evidence found in the surveys where participants tried to conceptualise their reasoning and justify choices and web searches [awareness]. Because only words were not significant in correlating with the architects’ thoughts, all references coded for that node were consulted to further develop the emerging picture. Six out of 10 participants made references to contextualisation with relevant indications of the social profile of the upcycling practice. One third of the participants related recycling and reuse to children or young people, and four connected upcycling activities to community, urban or landscape projects [awareness].

The connections and joints proposed within the surveys included lids, fishing lines, cable ties, holes, concrete, metal structures and steel plates, screws, welding, bolts and brackets. Eight out of 10 participants described possible connections to solve their proposals, but none provided detailed information about these connections within their models or drawings [awareness; effectiveness]. Four proposals from 3 participants considered the addition or combination of the lids and rails with other materials apart from those used as connectors. Other materials recommended included recycled wooden slats, pallets and glass.

Two designers showed some concern about material availability [awareness; efficiency; effectiveness]. One suggested collecting lids in train stations and schools. Another pointed that it should be a challenge to collect enough lids for the projects. The survey stated that participants had a “pile of rails” available for their projects, but no one questioned or estimated how many rails that pile would contain.

Material properties were investigated by the architects, but mostly in a superficial manner. Sixty percent showed concern about the properties of the materials available. The majority of participants gave only slight consideration to such conditions as colour, size, shape and weight. Two participants conducted more comprehensive research into properties, and both considered that research in their proposals [awareness; efficiency].

Interior architecture proposals for the lids included a bubble diagram (to be used as a flow diagram); door stops and knobs; table leg bases; lamp shades, light fittings and light fixtures; jewellery; cladding; fruit bowls; seats; toys; and mats. Architectural or urban suggestions cited mosaic pictures, tunnels, street art, wall panels and playground walls, screens, shading structures and Way find assistance signals. Interior artefacts related to light fittings (e.g. fixtures, lamps, table lamps and lights) appeared frequently. Cladding was suggested twice, and architectural walls, panels and screens were also commonly cited.

In relation to the rails, interior architecture proposals included wine racks, door handles and furniture. Urban or architectural recommendations consisted of landscape pieces or sculptures, columns, outdoor furniture, structural elements, sliding door elements and porticos. Furniture and structural elements were the most common proposals.

## 4.6 Summary

This chapter referred to the first project which aimed at empirical data collection and analysis. Reflective Rematerial Interaction (DS-A) was carried out with experienced designers who performed design activities mostly related to the discovery and definition moments of ROD. This chapter concluded with a description of the patterns found in the participants' strategies, tools adopted and material explorations. Appendix A provides the full set of classification sheets, word clouds, node references, and observation and analysis tables developed in this project.

## Chapter 5 Intuitive Rematerial Interaction (DS-B)

DS-B included a content analysis of retrospective visual data and fieldwork notes. The data collected were used for the development of an attributes matrix related to the rematerial-oriented design process as it was realised by second-year interior architecture students. The project looked mainly at the development and delivery phases of ROD through the examination of design processes, photos, drawings and models generated. The matrix crossed design attitudes and outcomes to determine potential causal factors. The students designed and built self-supporting panels using uneven decommissioned weapon parts, and the design process was carried out for over 60 days.

### 5.1 Objectives

The main goal of the methodological approach for this project was to detect aspects of design decisions and strategies related to ROD, especially within the development and delivery moments, and their potential effects on upcycling materials, elements or structures. This was the second step towards understanding and conceptualising ROD. This project aimed to

- recognise strategies adopted before and during design development and product deployment,
- identify and categorise items in the process that demanded different approaches compared to design with conventional materiality,
- relate design decisions and strategies with outcomes to recognise performance indicators, and
- consider causality elements and evidence about how they influenced design outcomes.

### 5.2 Participants

This second project looked at repurposing design activities performed by a group of novice designers composed of 31 second-year students from the School of Built Environment, School of Architecture and Interior Architecture, at Curtin University who were enrolled in the Interior Architecture Expressive Structures Studio unit in 2015. The unit had two prerequisite studios: Tangible Environment and Ephemeral Environments. The textbooks suggested are related to form, function and structural subjects.

## 5.3 Materials

### JOURNAL NOTES

Field notes taken during the study focused on observing pre-design approaches, formal composition, documentation methods and redesign strategies. Those themes were not fully defined through these observations and were developed throughout the coding and analysis processes.

### PDF DOCUMENTS

PDF files containing design documentation were developed by the students during the studio and were part of the content analysed in this project. The documents contained descriptions, graphic drawings and structural studies from the design proposals and were uploaded to NVivo. Each student participant delivered one or two PDF panels.

### PHYSICAL MODELS

The students built two types of models during the unit. In total, they constructed 31 models using cardboard (with or without the addition of supplementary material) in the first stage. After determined triage, five out of the 31 models were reconstructed using provided decommissioned weapon parts. The models were analysed onsite and through photographs uploaded to NVivo.

### NVIVO

NVivo, the CAQDAS used previously in this research, was also utilised in DS-B to aid data management, coding, analysis and visualisation.

## 5.4 Procedures

This project primarily investigated the development and delivery stages of ROD as performed by 31 novice designers from Curtin University's Interior Architecture Expressive Structures Studio. Content and protocol analysis were applied as principal techniques. NVivo supported the structuring and visualisation of the data.

The syllabus of the unit emphasised that participants would be expected to *“explore the nature of structures and their principles to gain an intuitive understanding through model making, experimentation, technological methods”* (Interior Architecture Expressive

Structures Studio, 2015). In this unit, students were expected to engage with intuitive structural analysis and reinterpretation of structures and parts of decommissioned weapons<sup>1</sup> using experimental construction and geometrical modification.

Over the course of 9 weeks, students were required to design and build a full-scale, self-supporting structure measuring 1.2 m x 1.2 m. During that time, they had access to six boxes (17 litres each) of material when working in the workshops. To meet institutional policies for health and safety, the weapon chunks could not be removed from the workshop and could not be photographed or have images published on social media before the completion of the project. Pieces were composed of wood handles, single and double metal barrels and others, all in different shapes, tonalities and sizes (see Figure 5.1).



**Figure 5.1.** Samples of material available for the project.

In the first three weeks, students focused on the design development and documentation of individual proposals to be prototyped in cardboard. The assessment of the cardboard models followed predetermined criteria, and five out of 31 were selected for construction with the real pieces (see Figure 5.2).

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<sup>1</sup> The weapons were decommissioned by the Property Management Division of Western Australia Police. The result of this operation was that the weapons were dismantled into a set of parts that were no longer active in their original function but were still visually related to the iconography of fire and cutting weapons.



**Figure 5.2. Models with decommissioned weapon parts.**

The choices for the refinement of the proposals were based on the coherence of the documentation, correct prediction of weight force paths, compression and tension elements in the structure, the ability of the model to support itself, the detail and appropriateness of connections, and material exploration. Students were subdivided into five groups whose assigned leaders were the authors of the selected proposals.

The workshops were equipped with a broad range of woodworking and metal fabrication machinery and tools. Before accessing the space, the students received training on how to handle equipment and operate some of the machines. They were supervised and assisted at all times by skilled technical staff during the making stage. Risky or complex activities, such as running the CNC machine or cutting hard metals, were always performed by those professionals.

Field notes taken during the process focused on observations of pre-design approaches, formal composition, documentation methods and redesign strategies. A content investigation of the visual data, such as photos, drawings and models, generated during the progression of the unit was concomitant to the field notes. The corresponding collected data were coded using NVivo for analysis (see Figure 5.3).

Thirty attributes were defined based on design strategies, documentation, material learning and preparation, and redesign tactics for their potential impact on repurposing efficiency. Those non-numerical attributes were classified as material information, pieces and joinery, documentation, formal composition or building processes and were evaluated in accordance with the case node created for each student (see Table 5.1).

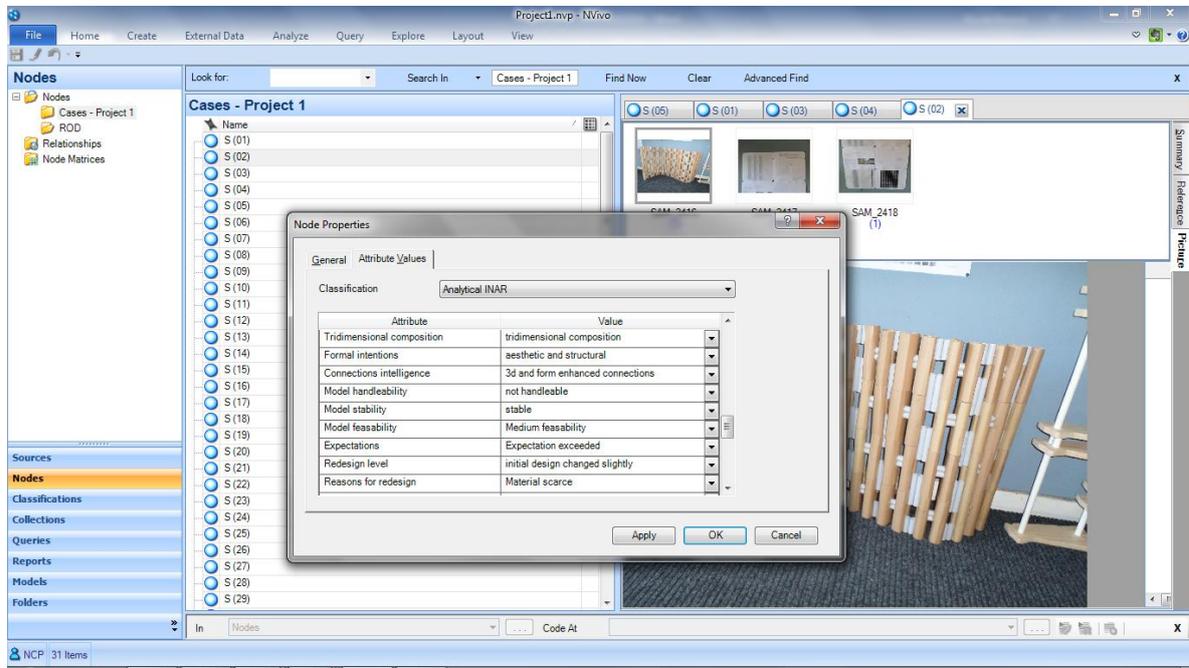


Figure 5.3. Data organisation in NVivo: Case nodes, related data and attribute values.

Table 5.1

*Non-Numerical Attributes Related to Each Case Node*

ATTRIBUTE		DESCRIPTION/OBSERVATION FOCUS
DOCUMENTATION	Model materials	Materials used in the proposal, such as cardboard, plywood or MDF, PVC pipes and wood rods.
	Details consideration	Evidence of concern about the real form/ details of the materials to be used (the weapon parts)
	Proposed connections	Connections definitions and representation
	Documentation quality	Comparison between drawings and models to identify the reliability between them; searched for necessary drawings and building details
	Documentation methods	Methods used included hand drawing, CAD drawing, other mock-ups and CAD-based hand drawing (transparent paper over a printed CAD drawing).
FORMAL COMPOSITION	Formal connections	Exploration of potential connections between two pieces, three-dimensional thinking, advantage taken from the original pieces adopted or forced joinery
	Formal intentions	Evidence of justification of the formal decision, including clear aesthetic, clear structural, aesthetic and structural, or not noticeable.

	Model feasibility	Feasibility of the execution of the model under ordinary skills and infrastructure conditions
	Model handleability	Observation about whether the mock-up was handleable and easy to carry
	Model stability	Behaviour of the model and its stability (and in which conditions)
	Modulation	Evidence of modulation and how it was presented in the models observed
	Tridimensional composition	Implementation of three-dimensional thinking while designing the model
MATERIAL INFORMATION	Material availability	Evidence of concern of wary use of material to avoid a shortage
	Concept development	Evidence of existing concepts or justifications for the proposal
	Material properties	Evidence of knowledge and awareness about the materials properties in documents assessed
	Search of precedents	Evidence that the student has searched for precedents or examples to inspire the concept adopted or proposed
PIECES AND JOINERY	Connections intelligence	Types of joints proposed were biscuit joint, glue, bolt and screw, wire, metal strips, metal studding ROD, welding an unclear
	Cuts of pieces	Cuts of pieces included wood whole, wood transverse, wood longitudinal, metal pieces unified sized and metal pieces diverse sized
	Recognition scale	Recognition of the pieces at room scale or detail scale or if they could not be recognised.
	Types of pieces	Description of the types of pieces proposed in the model: wood handle, wood forestock, double metal barrel, single metal barrel
BUILDING PROCESS	Expectations model x as built	Outcome quality between model and final installation for those built; outcome within the plans and cardboard model for those not built.
	Items redesigned or adapted	Adaptations, including the addition of pieces and the adaptation of joints and shape
	Manufacture skills	The skill level of the students to deal with the manufacturing process and whether they have searched for support
	Reasons for redesign	Reasons for adaptations, including material condition inappropriate, material scarce, shortage of time, design fail or lack of appropriate tool
	Redesign level	How much the design has changed between the cardboard proposal and the real panel made of real weapon parts.

To isolate factors that influenced the process, the researcher compared the attributes associated with expected and unexpected outcomes (e.g. stability, feasibility, redesign level, malleability and formal exploration) with selected attributes related to design process and decisions. From the 31 cardboard proposals, the classification of redesign and construction decisions incorporated only those five designs further developed using real pieces. Combinations were produced and visualised through 74 tree maps of attribute value combinations, as shown in Figure 5.4. The establishment of the combinations was

guided by a matrix of attributes, in which all the relevant groupings were checked and numbered. A total of 32 attributes were accessed in the matrix, and tree maps were generated from single-themed, double-themed and triple- (or more) themed visualisations.

To facilitate the visualisation of the situation of each combination, colours were assigned to the values. Whenever the attribute was connected to the outcomes, green, blue, yellow and red, respectively, denote a range from highly positive to very poor results.

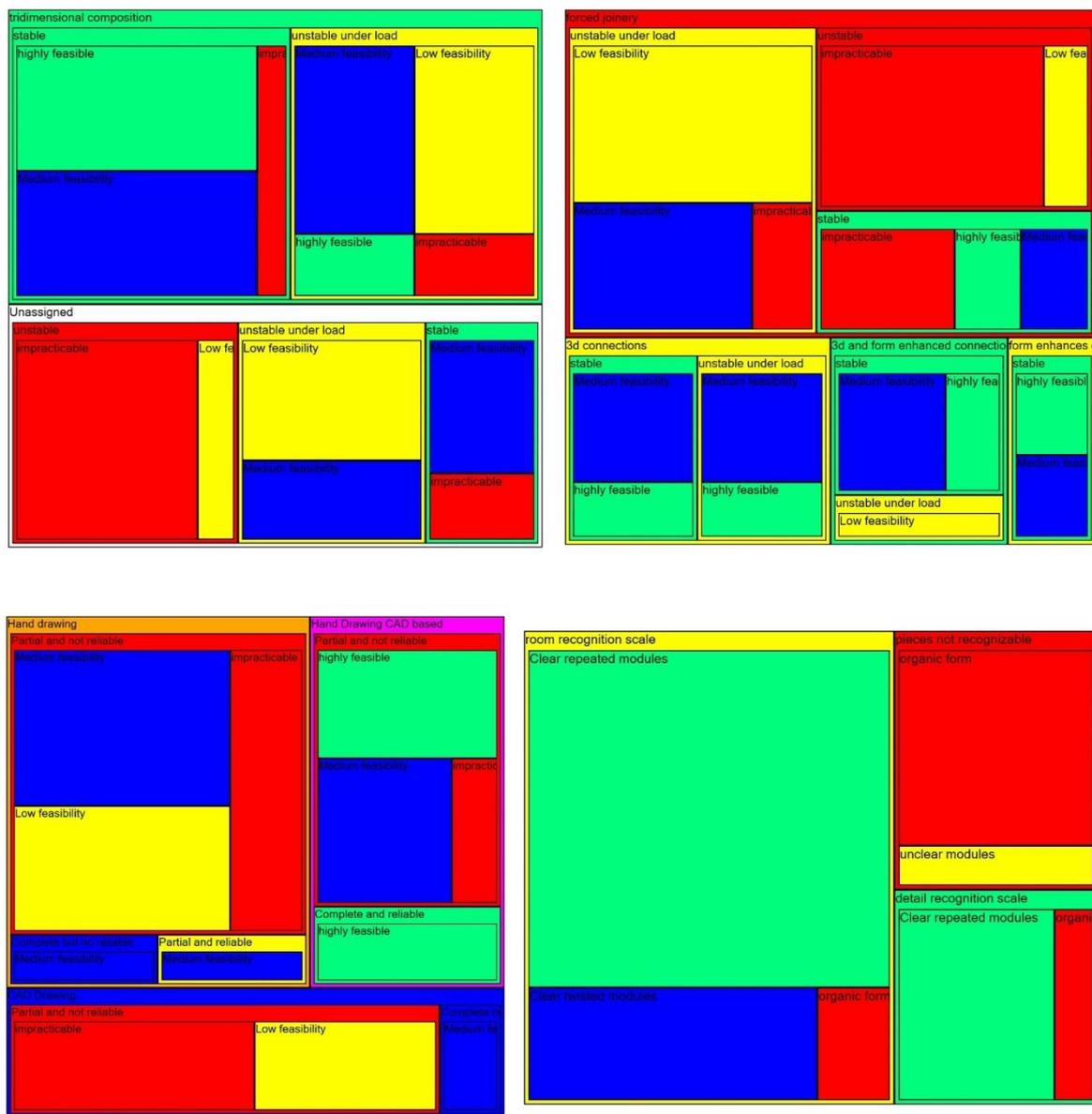


Figure 5.4. Examples of tree maps of attribute value combinations.

After the tree maps were generated, read and examined to identify attribute value combinations, a causality table (see Table 5.2) was developed to organise and summarise potential positive and negative causes and effects within the attributes assessed.

Impressions and observations related to each combination were described for a posteriori analysis of the results.

Table 5.2

*Causality Table of Combinations*

TREE MAP	CAUSE	POTENTIAL EFFECT/ASSOCIATIONS	
		POSITIVE	NEGATIVE
<i>Number</i>	<i>Value attributed</i>	<i>Related outcomes</i>	

The table was minimised and reorganised into 29 positive and negative attributes relevant to both cardboard models and final structures built with the weapon parts to simplify the process of drawing conclusions. Part of the combinations drawn, especially those related to what pieces were chosen and how they were cut, were only descriptive in character.

## 5.5 Results

This section sums up the implications of the novice designers’ approaches and decisions. Data were retrieved from the classification sheet in NVivo, and the analysis was structured using tree maps and a causality table. The full classification sheet, tree maps and causality table as well as the whole set of observations and analysis tables for this experiment are provided in Appendix B. For isolating associations with process awareness, effectiveness and efficiency (according to the objectives of the thesis), the considerations made in this section were marked with the affecting factor(s).

From the analysis, there was evidence that the expectations from the plans were not met in the models for most of the proposals, although more than one third of the pupils did meet these expectations. Less than one tenth of the design proposals extrapolated the expectations, and all the proposals which expectations exceeded were built with real pieces [awareness; effectiveness].

Most of the students did not explore the potential connections between the two pieces, including three-dimensional thinking. Those proposals included trials for unclear or undeveloped connections, which were identified in the matrix as “forced joinery”. A minority of the participants took some advantage of the original form of the pieces, and a few proposals suggested tridimensional thinking about joints elaboration. In both cases, smart connections led to better results for proposals [efficiency; effectiveness].

More than eight tenths of the proposals did not consider specific details of the elements in design. Among this majority, approximately half have contemplated aesthetic and structural priorities; the other half looked exclusively at aesthetic or structural issues. Cases that considered the details of the elements predominantly had aesthetic and structural formal intentions and superior performance [awareness; efficiency; effectiveness].

Only one fourth of the participants considered the amount of material available for their proposal, with less than 20 percent showing any evidence of awareness of material properties [awareness]. One fifth of the groups whose models were built had no manufacture skill, and one fifth were totally skilled. Three of the total had partial skills; the more skilled the group was, the fewer problems were found during the building stage [awareness; efficiency].

More than half of the proposals used only cardboard. The other part predominantly consisted of models made from cardboard and a second material, such as wood RODs, PVC pipes, MDF or plywood. Only proposals that mixed cardboard and PVC pipes or wood rods had totally changed designs.

Among the models built, the majority (four fifths) had to be redesigned. However, half of those had unexpected shortages of material (which led to a slight change in initial design), and the other half had problems with the design proposal (the initial design had to be totally changed) [efficiency].

The clear majority of the proposals demonstrated no connections intelligence, but among those that did, most were built from cardboard or cardboard combined with another material. Conversely, the proposals made from only cardboard were the least handleable and were also associated with low stability [effectiveness].

A large portion of the design projects resulted in room recognition scale of the weapon pieces and was associated mostly with some modulation. All the models built with real pieces applied some modulation. The weapon parts could be recognised at room scale in most the proposals. There were an equivalent number of pieces that were non-identifiable or recognisable only in detailed scale. Relevant relations existed between documentation methods and redesign, and three-fifths of the built models were CAD-based hand drawings [awareness; effectiveness].

About one third of the students showed some evidence of concept development related to their proposals. Among those students, 80 percent also searched for precedents during the predesign stage [awareness].

Nearly five-sixths of the cases suggested the use of wood handles, including a combination of wood forestocks and single metal barrels or wood forestocks and single and double metal barrels, respectively. The second most common proposals involved wood handles with wood forestocks and metal pieces. Only one project included only metal pieces, and no proposal suggested the application of only one type of metal barrel. No relevant associations were found among the types of pieces applied and the design performance.

More than half of the models presented whole wood pieces as the main material combined with metal pieces of the same size. The second most popular combination involved metal pieces diversely sized or slices of wood. The other significant portion of the proposals suggested the use of either longitudinal or transverse cuts of wood pieces in conjunction with alternatively sized metal barrels.

The best results were achieved with hand drawing or CAD drawing completed with hand drawing [awareness; efficiency; effectiveness]. Apparently, CAD drawings imposed limitations on three-dimensional thinking and detailing definition during design development. Pieces seemed to be perfect and identical, and the functions “copy” and “array” deluded the novices regarding drawing precision. Details added manually seemed to increase the quality of the documentation.

Proposals that met or exceeded expectations applied clear modules or twisted models and represented tridimensional thinking in terms of formal composition. Modulation and tridimensional reasoning were both associated with models with good feasibility and stability [awareness; efficiency; effectiveness]. Concept development, a search for precedents during the design process, complete and reliable documentation, and early consideration of material properties and availability contributed to good performance [awareness].

## 5.6 Summary

This chapter described the second project focused on empirical data collection and analysis. Intuitive Rematerial Interaction (DS-B) investigated how novice designers’

decisions in terms of design and representation affected outcomes for upcycling. This project identified items related to documentation, formal composition and connections, material information and building processes related to the development and delivery phases of ROD. The full classification sheet, tree maps and causality table as well as the whole set of observations and analysis tables for this experiment are provided in Appendix B.

## Chapter 6 Skilful Rematerial Interaction (DS-C)

Project 3 closed the loop with organisational visits and semi-structured interviews with experts in ROD located in Melbourne, Australia. This project aimed to investigate design goals and strategies, performance, practices and standards in the industry to refine and validate the information generated from the previews projects. The interviews were transcribed and coded according to nodes encountered within the design activity clusters (discovery, definition, development and delivery).

### 6.1 Objectives

The final project aimed to validate and complete the information constructed through projects 1 and 2. The results from the experiments with designers with little to no experience with ROD (who performed the activity intuitively) guided the direction of the interviews with experienced designers. Thus, the objectives were to

- validate the factors of efficiency in ROD identified through less experienced designers' processes and complement those factors not yet considered;
- establish whether those factors were due to the level of skill or experience or were inherent to dealing with rematerial; and
- learn the position of experts associated with materiality, process improvements, and personal and organisational design strategies within real scenarios.

### 6.2 Participants

Project 3 involved visiting and interviewing the directors of two companies located in Melbourne, NSW, that had expertise in ROD. The companies, named Multiplicity and Phooey Architects, both had a diverse track record of implemented architectural proposals and awards connected with repurposed and reused resources and a strong commitment to materiality.

Multiplicity is an architecture practice founded by the co-directors, interior designer Sioux Clark and architect Tim O'Sullivan, who participated in the interview. According to Scruby (2011), artful adaptive reuse projects named this practice. The founders are gifted with the ability to recognise opportunities for ROD. They declared themselves to be lovers of raw material and are very enthusiastic about found material and preloved objects (O'Sullivan & Clark, 2016). Scruby (2011) described these designers as follows:

“Multiplicity’s deft hand at adaptive reuse was arguably what first put them on Melbourne’s architectural map, and their commitment to retaining existing structures (and preserving embodied energy) where other practices might take a more blasé approach to demolition is still central to their sustainability-focused philosophy.”

Phooley Architects was established in 2004 by architects Peter Ho and Emma Young. Their design philosophy was to reinvent every piece of so-called waste in an upcycling process. The practice has been an eager advocate for the process and has emphasised how materials are used rather than what materials are used (Butler, 2001). The researcher conducted an interview with Peter Ho (2016), who was currently completing a doctoral dissertation entitled “Upscaling Upcycling” (Ho, 2016).

## 6.3 Materials

### SEMI-STRUCTURED INTERVIEW

The researcher developed a document to guide the interviews based on the information generated throughout Projects 1 and 2. The same directive text was used for both interviewees.

### VOICE RECORDER AND COGI

A mobile built-in voice recorder was used to record the interviews as MP3 files. To facilitate the delimitation of the most relevant moments of the talk and provide backup for interview recordings, the researcher also used an application called COGI (Cogi Inc., Version 2.4.4) during the dialogues. COGI combines note taking and voice recording but records only the important parts of conversations and enables the addition of images, hashtags and text notes.

### MICROSOFT WORD

Word (Microsoft Office 365 ProPlus, Version 16.0.6925.1044) was used to transcribe the interviews and to highlight and manually code the conversations according to the nodes and themes identified in the previous examinations.

## 6.4 Procedures

Phooney and Multiplicity are architectural firms situated in Melbourne, Australia. Their architectural teams are specialists in consciously practising rematerial-oriented design. Therefore, to gain information about their experience and expertise and validate information collected from the previous projects, the researcher carried out the following steps: The companies were contacted regarding their willingness to take part in the research, and, upon positive response, a consent form and an information sheet were sent to each company. The interviews were scheduled and carried out. These interviews were semi-structured and covered aspects of the origin and viewpoints of the practices, the working teams and client profiles, harvesting and design strategies, techniques for material learning and information, and documentation and building processes.

Data were labelled and backed up upon collection. The conversations were transcribed and coded referring to the nodes created in the previous projects (DS-A and DS-B). New codes were added as complementary issues emerged during analysis based on the experts' practical experience.

## 6.5 Results

The Skilful Rematerial Interaction project was planned to gather real-life ROD experience from architects and interior designers with expertise in applying the process within real architectural design projects. The interviews were developed based on classifications identified in DS-A and DS-B and specificities of the industry and their practices. Data were retrieved from the recording files, and the conversations were transcribed and coded according to previous rematerial interactions perceptions.

During this process, new codes emerged and instigated additional reflexions. The coding structures for the interviews are included in Appendix C. In this section, the symbol [XNPY] refers to findings within the transcriptions' coding; and X may be substituted for M or P (Multiplicity and Phooney, respectively), and Y refers to the coding number (see Appendix C for coding numbers).

The four phases of ROD – discovery, definition, development and delivery – were mentioned by both interviewees several times. These design moments were approached as parent nodes with a collection of child nodes as sub-themes in conjunction with material information and ROD nodes (which also had related child nodes). The

description of the content coded for all these nodes is summarised below to structure the results of DS-C.

## **Discovery**

This moment in ROD occurs when the designer encounters the material (which may be one or more objects, elements or structures) with the potential to be upcycled. Discovery can happen intentionally or casually, which means that the designers could be searching for a suitable resource to respond to a design problem (the need is present) [PNP13;15;27] or that the resource has been found and has potential for later application (the need is yet unknown) [MNP54]. The discovery may happen while the designer is walking down the street and his or her attention turns to something that is potentially interesting [MNP1]. Alternatively, discovery may occur during building demolitions – for example, when resourceful designers are alert for material that might become available for upcycling [MNP37;57] [PNP27]. In this case, the focus is on dismantling the building and re-connecting it in a different way [PNP1].

Discovery is about finding materials with intrinsic beauty and exploring and understanding materials [MNP2]. It is also about seeing opportunity in what most would consider waste [MNP4] and thinking differently from the majority [MNP9;15]. Although architects are expected to have refined spatial visual capabilities and be attentive to these potentials, most do not have the vision or are not interested [MNP16;17].

The question that initiates ROD and introduces the discovery of rematerial is: What can be done with this? [MNP10]. Moreover, the awareness that every design will produce waste [PNP3] may lead to the following question: What can be done with that waste? Architects involved in upcycling maintain an alert eye for resources that may be available anywhere. They believe that collectables might be useful one day. An unknown future need for that resource drives professionals to find and collect materials and challenges them to discover the proper fit for the matter at hand [MNP1;38;54] [PNP10;17;27].

The process of finding and preparing materials requires effort, but interviewees indicated that the compensation is joy because they consider searching, finding and collecting materials to be a challenging and pleasurable activity [MNP18]. Moreover, as they become recognised for the practice, they also receive things that others are not able to reuse or restore [MNP24]. Designers need to be astute observers to catch precious opportunities [MNP14], especially when approaching old pieces. Materials from past

decades are often high quality; however, contemporary manufacturing has an ephemeral approach to prioritise short-term substitution [MNP57] [PNP26].

During the phase in which ROD is still being considered, two critical factors require immediate reflection. Time and space are aspects of high relevance in the discovery phase and may define the promise of a given project [MNP55] [MNP54]. The process of giving material a new life takes time not only to complete proposals but also when the material is saved for later because there is no immediate need [MNP38] [PNP17]. Commonly, however, the opportunity is lost when designers realise that material saved for later will not be useful or will occupy space indefinitely. [PNP5].

The experts in ROD interviewed for this study had considerable storage space available for the resources saved for later [MNP25]. Both interviewees agreed on how important it is to build an inventory of material and organise or even catalogue all the related information so that matter can be accounted for more easily [MNP54] [PNP28;31;32;33;34].

### **Definition**

Basically, the current need, the scale and the amount of the material discovered directs the moment of definition in ROD [PNP6]. Unique pieces are mostly destined for interior design or decorative purposes, whereas the availability of multiples enables the elaboration of architectural elements, such as ceilings, panels and walls [MNP11]. Repetition is an interesting concept for recycling material [MNP10], and sometimes, when defining the project, designers may notice that the resource immediately available is insufficient; here, another design problem emerges in relation to material availability.

Another determinant is the cost-benefit analysis, which should be conducted before the proposal is fully developed. ROD is labour intensive and not always cost effective [MN55] and, therefore, should be balanced with the added value of the customisation, personal attachment or history of the material and the sustainable intent [PNP10] [MNP55].

Material information becomes even more important during the definition moment because it may limit the options for repurposing [MNP26]. It is important that material properties, dimensions, forms and, conditions be fully learned and documented in conjunction with the conceptualisation of the project [MNP27;41] [PNP26].

Upcycling is not only a domain for an organic approach because contemporary buildings also may be derived from discarded material in their second lives [MNP22]. Regardless of whether the material is upgraded to a goal definition stage because its reuse is eminent and the need is present or will be saved for later, documentation of material information, potential applications and insights about means for connecting it is also important at this stage [MNP27;41].

The interviewees believed that is best to have an immediate, onsite application for extending material flows to avoid labour-intensive transportation and storage [MNP37] [PNP29]. Ideally, goal definition for a project should occur onsite as the material is discovered [MNP37].

When dealing with recycled material, designers need to rethink how to connect these materials. Usually, the simplest ways work the best [MNP5]. Simplistic solutions for joints and connections [MNP6] and materials that do not require specialised manufacturing labour [MNP8] will increase the performance of the design.

## **Development**

During the development phase of ROD, it is important that the designer has already learned and understood the material and foreseen the main constraints have been foreseen. Documentation with precise detailing [MNP33] [PNP30] is key because it may lessen misconceptions and the need for redesign in the delivery stage [MNP49].

While detailing using computers, designers should take extra precautions to avoid missing tactility [MNP43]. Although BIM, for example, enables information management and three-dimensional manipulations [PNP35], detailing with digital tools might lead to a false indication that components are perfect, which is rarely true of recycled materials. These materials are rarely homogeneous, and even the smallest details must be considered to achieve successful design outcomes [MNP5;27;44].

Consensus among interviewees supported the development of simple solutions and the definition of standardised or simply implemented connections [MNP40;48] [PNP36]; however, the designer should keep the realms of the materials rather than trying to turn them into something they are not [MNP7]. Material repetition, modulation and attention to patterns increase the performance of rematerial designing systems considerably. Manufacturing proposals that the designer fully understands, from precedents research or previous experience, will enhance the chances for satisfactory material extension.

## Delivery

Because of ROD's craft profile, the roles of the designer and the maker become essentially adjacent, and the awareness of the manufacturing process is a determinant for solid project development with minimal redesign occurrences [MNP24] [PNP23;30]. In some instances, the designer and even the user may be directly involved in the making or building process [MNP46]. Alternatively, straightforward, effective communication with the builder can make the difference when dealing with upcycling [MNP32]. This interaction must be clear and should be established through adequate documentation and, in some cases, complemented onsite. [MNP30;40;45;46] [PNP30].

Delivery is about concluding the design. For customised rematerial design to produce goods ready to be used, labour with manufacture skills and appropriate tooling are essential to materialise the established goal [MNP6;24] [PNP24]. The materialisation might be carried out by bricolage, DIY means or builders and makers who are conscious and connected with the process [MNP45;46] [PNP12;24;38].

Successful strategies for linking builders to ROD include obtaining reliable documentation and certification of their understanding; simplifying design and deep detailing of proposals they are not used to [MNP12;46] [PNP30]; and adopting standardised systems for building structure and recycled materials added subsequently [MNP40].

Upcycling and bricolage (or DIY) are potentially integrated and commonly considered in opposition to the rational, focused reasoning employed in the engineering field. Systematising information might direct the spontaneous attitudes of craftsman and *bricoleur* while bringing their ludic *savoir-faire* towards a more conscious and efficient activity [PNP8;9].

## 6.6 Summary

Chapter 6 detailed the third project focused on empirical data collection and analysis. Skilful Rematerial Interaction (DS-C) examined ROD performed by designers with high levels of expertise in the practice to validate and complement the information extracted from the previous projects. This chapter revealed further rematerial interactions, such as time and space, and identified constraints and motivators for the development of the activity. Appendix C provides a detailed set of transcripts developed in this project.

**PART III**  
**Prescriptive Study**

## PART III – Prescriptive study

*“No design is possible until the materials with which you design are completely understood.”* (Rohe, 1938)

Part III presents the findings of the thesis, addresses the factors influencing rematerial interactions and describes the process improvements for ROD.

Chapter 7 structures the raw knowledge and reflections obtained from the empirical projects to complete the ROD framework presented in Chapter 2. This chapter also contextualises the reference model in an actual situation and presents the impact model, conscious rematerial interaction, with the suggested process enhancements. It demonstrates how to improve information flow and identifies the relevant factors related to constants, variables and design decisions that are manageable by the designer.

Chapter 8 completes the investigation with the contributions and limitations of the thesis. Future research opportunities are listed, including the potential for a computer-based rematerial informational modelling tool.

# Chapter 7 Conscious Rematerial Interaction

## 7.1 Unconscious Rematerial-Oriented Design

Design invariably begins with an initial stage focused on a problem or need and, to obtain favourable responses to design questions, designers make use of different tools and methods. The outcomes depend not only on how those tools and methods are applied but also on the background built before the implementation begins. According to Wiggins (1989), design can be framed into constants and variables based on substantive knowledge (which relates to what the designer knows) and process skills (which refer to what a designer does).

For material interactions in ROD, the resources available (including elements, pieces and structures) and all related information are constants in the process. The skills, aims, preferences, experience, actions and environment of the designer englobe the variables. The interaction between constants and variables influences design decisions and the final product.

When exploring materiality in traditional design, the designer looks for experimentation, sensations and specific tactile properties in addition to technical aspects. Within the ROD process, the material must be understood first, and material information is a requirement for establishing project goals. Moreover, because ROD generates customised products and every proposal is unique, the variables together with all the constraints on the design context must be acknowledged, considered and, when possible, moulded.

Practitioners of reflective and intuitive ROD interact with variables and constants mostly instinctively. The material is learned partially through manipulation (physical or virtual) and formal experimentation. These designers touch, twist, bend and compose the material manually or mentally, and then they progress to noticing general features and researching specific characteristics. However, only a few stands to the importance of how superficial learning of material in early stages of ROD may compromise, delay or prevent the conclusion of the project.

In contrast, experts who perform skilful ROD are entirely informed about the constants and variables of the process. They have built consistent knowledge about the constraints and potentials of the practice and developed cognitive strategies to deal with rematerial. This awareness, which may be innate among gifted craftsmen, is strengthened with

routine experimentation and practice. Nevertheless, there is no data management in this practice. This information is mostly unstructured and is not communicated or transferred during the phases that precede material re-contextualisation, causing relevant information to be disregarded, lost and made inaccessible and increasing redesign incidences and the abandonment of resources saved for later. Figure 7.1 represents the reference model considering the present situation for ROD.

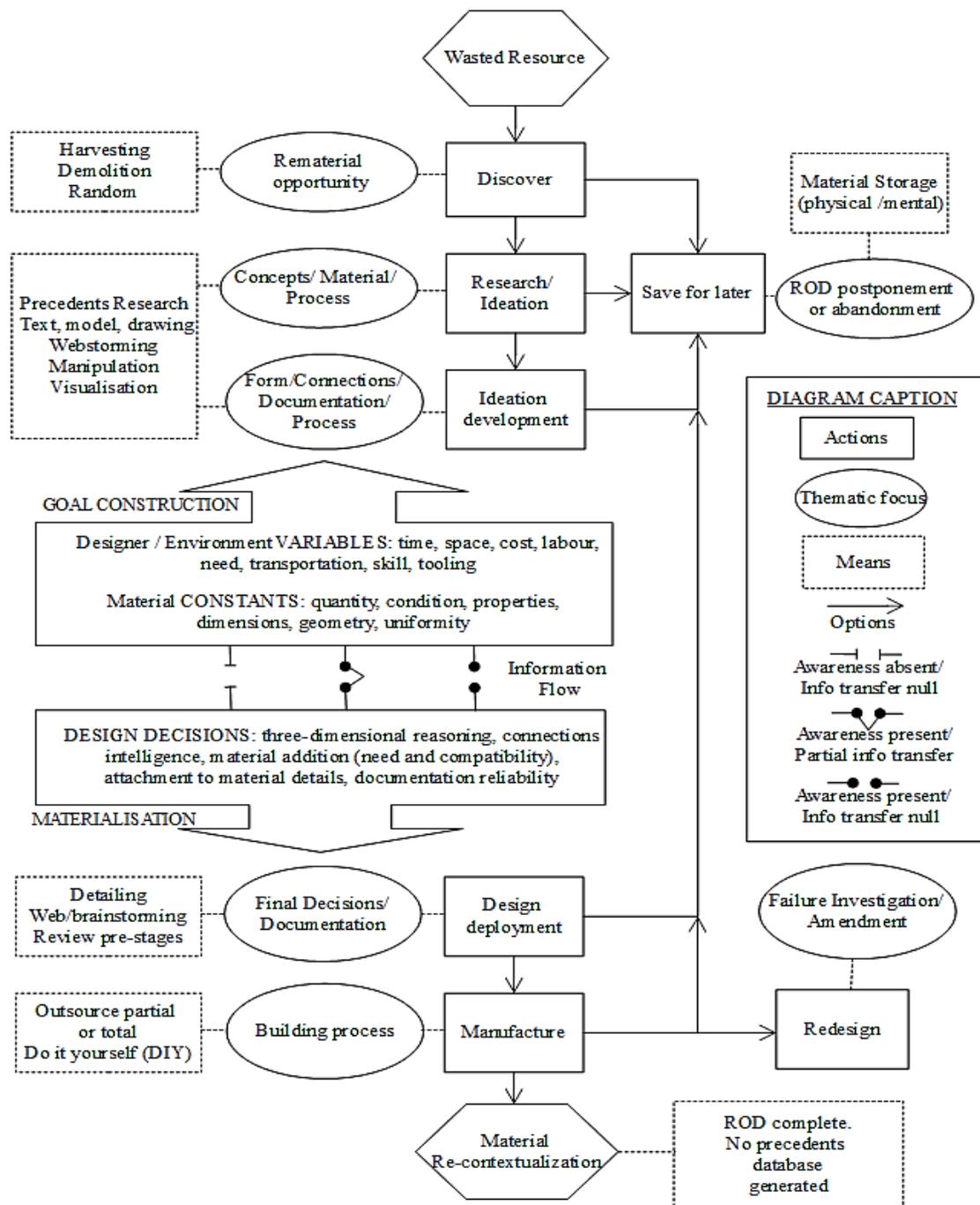


Figure 7.1. The reference model for ROD.

Given this scenario, the most relevant weakness in ROD in terms of productivity within the three categories is the lack of a structured approach to manage relevant ROD information – constants and variables – direct research and ideation, continuous updates of data, communication, transfer and storage with prompt accessibility. Thus, the process would be supported by informed decisions, even for propositions that were interrupted in early stages and have been saved for later, to rescue these proposals more promptly at appropriate moments.

As shown in the reference model, the fundamental constants of the process refer to materiality. Material learning requires the designer to acquire and transfer accurate information, and those are constants before the progression of acts that enable re-contextualization. Throughout ROD, however, those constants are prepared, transformed and adapted conforming the constructed design goal. Therefore, they are only constants in early stages, but the designer must remain conscious of them.

In contrast, the variables include the designer and the environment in which ROD will occur. The variables affect and constrain the opportunities for the constants to be re-contextualised. Awareness of the variables encourages essential changes and updates to enable more appropriate design decisions.

Within the existing categories of rematerial interaction, cognitive strategies for research and ideation are elected and applied instinctively. The design decisions result from the designer's substantive knowledge and process skills. Moreover, when performing upcycling in architecture, the designer will have a greater chance to achieve a positive outcome if the design is led by informed choices that are relevant precisely to that unique framework.

## 7.2 Conscious Rematerial-Oriented Design

The impact model, conscious rematerial interaction, has been developed to address the crux of the problem identified in ROD – namely, the acquisition, transference, connection and consideration of quality rematerial information throughout the activity progression. This model assumes that directed, cyclical and continuous input and contemplation of data regarding crucial ROD aspects (variables, constants and decisions) will enable a more aware, effective and efficient process, increasing the chances for positive outcomes even when the rematerial is being saved for later.

To achieve this goal, this thesis proposes rematerial information modelling (REMIM). REMIM can be accessed and nourished throughout the transition phases as the designer discovers the material, accomplishes the initial research and ideation, and makes decisions to materialise the established goal. At the beginning of the process, the set of factors to be edited is standard for all cases of ROD and gains clarity as data are collected. Thus, the range of options may increase or decrease according to the existing conditions and the choices made.

The information manager is not intended to restrict the creativity of the designers but rather should induce productive inventiveness and management of constraints that lead to decisions directed towards feasible proposals. It is based on generating and maintaining dependency structures to reflect changes in the design learning and emphasise conflictual knowledge. Entities such as material size (a constant) and formal composition (a decision) may be associated, leading to the emergence of potential conflicts.

Figure 7.2 presents the impact model for conscious ROD. REMIM is initiated with material discovery and not only drives the formation of process knowledge and design definitions but also links the information to each development point. REMIM intervention should occur during at least in three basic moments of ROD: rematerial information learning, moulding and assisting. At these points, information flow, awareness and connectivity are crucial. Nevertheless, this approach may be applied on demand with no restrictions.

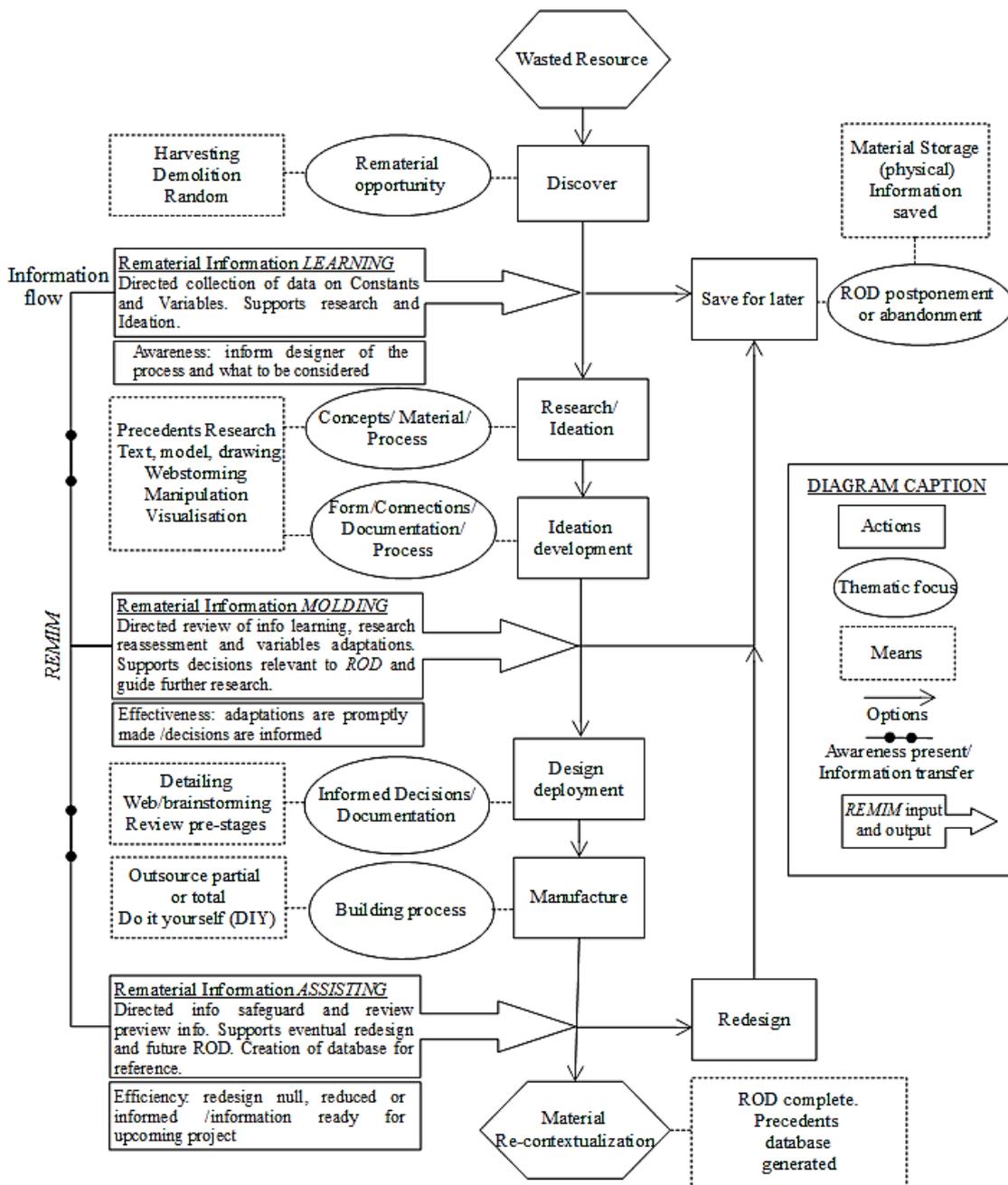


Figure 7.2. Impact model for conscious rematerial interaction.

At the learning stage, REMIM supports the designer's strategies for finding and learning appropriate information to initiate the research and ideation of the project depending on the rematerial intended for re-contextualisation. The material, the designer and the environmental understanding are the primary foci at this stage. Secondly, as the goal for rematerial is constructed or set, information moulding through REMIM based on the original documentation will support decisions that are relevant to ROD and allow updates to the on information originally documented on material, designer and environment.

Finally, when delivery is accomplished or the need for redesign is noticed, the information manager can reassess the process to gather data for complete documentation of the informed procedure.

The next section of this prescriptive study presents further details on REMIM. The proposed support, however, has not yet been finalised, and further research is necessary to develop additional conceptualisations of REMIM and test its operability in real design scenarios. A prototype of the instrument might serve as a foundation upon which to build computer-based software to enable conscious rematerial-oriented design for designers with different levels of experience.

### 7.3 *REMIM* – Rematerial Information Modelling Tool

This section describes the preliminary content for REMIM. The prospective instrument is designed to support architects and designers when they need to collect information about, evaluate, consider and model several factors relevant to the wasted resource intended for re-contextualization during ROD.

REMIM is intended to direct and foster tasks that architects and designers perform randomly during the skilful, reflective or intuitive ROD process. This model will support the user in adopting and documenting more conscious and productive choices, motivate creativity and provide more efficiency in workflow. The following paragraphs illustrate an application of REMIM that may be presented in an interactive spreadsheet format initially. This approach will enable the understanding and potential of this tool, yet introductory.

#### An illustrative example of REMIM application:

There has been a demolition. An architect called Bruno steps onto the site and notices a pile of unique steel pieces that are located near the front and about to be discarded. Bruno decides to take a closer look. At this moment, the material has been discovered, and it becomes rematerial.

Bruno is interested in reusing those pieces, but he is not sure where or how to reuse them. He needs to resolve rapidly because the site must be clear by the end of the week. Although he is currently developing a housing project for that site, it is unclear whether there is enough material or whether it will even fit that building or be accepted by his

clients. Then, Bruno chooses to use REMIM as an aid to collect some information and help him make those early decisions.

REMIM starts with two options: (a) new rematerial and (b) rematerial rescue. Under “new project”, there are two tabs. The first one relates to ROD constants (material), and the second relates to ROD variables (designer and environment). Bruno goes on to fill in those requesting cells shown in Table 7.1.

Table 7.1

*REMIM Tab: ROD Constants*

CONSTANTS	Description	REMIM information modelling
Profile	General description of the resource, including name and intangible values, impressions, sensations and highlights.	The user manipulates, absorbs and analyses the resource. Physical, mental and digital manipulation are encouraged. Record of findings is requested.
Precedents	Research of previous design proposals that include the same or similar material	Name(s) adopted previously to define profile will be accessed for automated precedents webstorming and added to process words, such as reuse, recycle, upcycle and innovative. Record of findings will be saved.
Quantity	Exact or very approximate number is required	User learns and documents the number of pieces available and accesses the possibility to acquire more in case it is needed or alternatives must be adopted.
Condition	Assessment of the need for treatment and search for unexpected material conditions	The user is encouraged to manipulate the resource again when possible to investigate specifics, such as material breaking under gentle pressure or hidden properties (one material covering another). Record of findings is requested.
Properties	Assessment of general physical/chemical properties	The user is encouraged to research essential material properties, such as weight, resistance to traction and compression, flexibility, and behaviour under specific conditions (i.e. weather). Designer may be linked to automated webstorming (web search of properties + material). Record of findings will be saved.
Dimensions	Dimensional assessment of resource	The user is taken to learn and document exact dimensions of the resource.

Geometry	Formal assessment of resource	The user is taken to manipulate the material and research and document its formal characteristics. The designer is led to observe formal potentials for connections and experiment with tridimensional composition and repetition. Record of findings is requested.
Uniformity	Evaluation of uniformity or detachability	The user is led to investigate how uniform the resource is, whether it has detachable parts and its compatibility with materials that may be added to the proposal. Record of findings is requested.

Information about the constants should be provided in the learning stage because these constants are decisive factors for informed design decisions. In some cases, the variables may not be provided initially; however, awareness about variables will make the user attentive to those aspects. The variables are presented in Table 7.2.

Table 7.2

*REMIM Tab: ROD Variables.*

VARIABLES	Description	REMIM information modelling
Time	Estimate of time for materialising the proposal/availability of time	User is led to estimate time to be spent on materialisation and must consider beforehand to allow that time.
Space	Availability of space for storage	A positive response will cause a request for more details on space. A negative response will warn the user that immediate ROD is required.
Need	Existence of a current need or goal for re-contextualisation	A positive response will cause a request for more details on the goal. A negative response will link the user to automated webstorming (image web search using process words + material) and also exploration of the potential social profile of rematerial
Cost	Indication of prospective savings or increase in costs	An indication of savings or cost increases will require more details on reasons, such as other material additions or labour-consuming costs.
Labour	Information on who will be the maker and manufacturer or build the proposal	User is led to estimate time to be spent on materialisation and consider beforehand to allow that time.
Transport	Need and feasibility of material transportation	A positive response will cause a request for more details on transport.

Skill	Information about the skills needed for manufacturing the proposal and how the maker dominates those skills	More details on skills and processes will be requested to lead the user's process learning and, once the process is described, the designer will be linked to automated webstorming (image web search using process adopted + material).
Tooling	Information about necessary tools and availability for manufacturing the proposal and how the maker dominates those tools	More details on tools will be requested to lead the user's process learning. Depending on tool availability, the user will require more research on alternative procedures.

As Bruno checks, researches and fills in the requested information, he figures out the initial conditions for performing ROD. REMIM generates reports on demand to facilitate a balance between potentials and limitations in terms of design decisions. The tool warns him that because there is a shortage of space at the moment for storing that material, it should be used on the site for that housing project.

He is now aware of the exact number of pieces, their irregularity and the rusted condition of part of these pieces. He also knows the hardness of the material and that the builder currently working with him may not have the essential cutting tools, so it may be necessary to lease appropriate tools or adapt the design goal.

Bruno found an intrinsic beauty in those pieces, and he is sure they will confer a special touch to the upcoming house. While filling out the spreadsheet, he is directed to check thousands of precedent web searches on recycled, reused, repurposed and upcycled steel, and he develops some sketches himself. All that documentation is added to REMIM.

After some ideation, Bruno considers designing steel pillars, which will remain apparent in the living room. Given the irregularity of the pieces, however, he is unsure about the formal composition and connection between parts. To further the design decision-making process and refine his proposal, Bruno continues to access REMIM, now using the "Decisions" tab illustrated in Table 7.3.

Table 7.3

*REMIM Tab: ROD Decisions*

DECISIONS	Description	REMIM information modelling
Concepts	Encouragement of the definition of a concept for the proposal, which may be based on precedents	Initial ideation results, precedents and profile (from constants) are assessed, and user is encouraged to record

		ideation towards the development of design concepts.
Scale	Encouragement of the definition of a scale for the proposal, which may be interior, architectural or urban	Results from material dimensions and quantity (constants) are accessed, and according to designers' definitions on the scale, the precedents webstorming is refined to include the focused design scale. Records of findings will be saved.
Functions	Encouragement to explore and integrate functionality, structural and aesthetic inquiries	The user is taken to manipulate, absorb and analyse the eminent proposal. Drawings, sketches, physical, mental and digital manipulation are encouraged. Record of ideas is requested.
Formal composition	Encouragement of precise, detailed and smart formal decisions	The user is taken to consider modulation, repetition of pieces, tri-dimensional thinking and composition to take advantage of form features and details. Record of definitions is requested.
Connections	Encouragement of precise definition of connections	The user is taken to define every detail of connections, slots and joints and record them. Automated image webstorming of possible connections solutions will direct research on the topic. Record of definitions is requested.
Finishing	Encouragement of precise definition of finishes	The user is led to define design finishing precisely. Research on the process to be adopted will be encouraged. Record of definitions is requested.
Material Preparation	Encouragement of research and learning of processes necessary to prepare the resource	The user is led to understand and define processes needed for material preparation, including recovery, cutting, transforming and assembling. Research on methods to be adopted will be encouraged. Record of definitions is requested.
Systems Integration	Assessment of how the proposal integrates surrounding systems	The user is led to consider potential impacts of the proposal in the future containing space or system, including physical, structural, aesthetic, functional and sensorial. Record of impressions and findings is requested.

Redesign	Assessment of potential causes for redesign and encouragement for redesign accomplishment	The user is directed to investigate causes for a redesign, including lack of details definitions, unawareness of material condition and shortage of material, and ideation towards the finding of solutions is encouraged. Record of findings is requested.
Documentation	Encouragement of detailed and reliable documentation of the proposal	Designer skills are accessed for documentation, and documentation methods are suggested according to those skills.

As Bruno completes the requirements of the tool, he makes informed decisions about re-contextualising most of the steel parts. His team is now ready to complete a precise and detailed documentation for the builder because REMIM reports are organised to be exported. Nevertheless, the architect is conscious that one third of the pieces will not be utilised in this project, and the client is inclined to save that material for a future renovation. When this moment approaches, the database generated through REMIM will be available for reuse in the mode “Rematerial Rescued”.

This is a basic skeleton for the instrument. Its functions support, assist and guide rematerial learning, methodical design activity and knowledge building, structured documentation of design data, and retrieval of knowledge, methods, tools and design data for reuse. Additionally, as an integrated computer-based system, REMIM may frame supplementary digital functionalities to boost the exchange of material information.

## 7.4 Summary

This chapter contextualised ROD theoretically and presented the design conditions – mostly unconscious – in which the practice currently occurs. This chapter also presented the impact model (conscious rematerial interaction), identified the process weaknesses and suggested support. In addition, this chapter demonstrated means to enhance information flow and identified factors related to constants, variables and design decisions that can be managed positively by the designer.

# Chapter 8 Conclusions

## 8.1 Reflections

Rematerial-Oriented Design (ROD) is an unpredictable non-linear activity. The material to be contextualised is inserted in the traditional process in different stages, depending on current objectives, the situation of the potential project or the phase of design progress in which the material is found or discovered or becomes available. Regardless of these irregularities, two main critical moments characterise the process: goal construction and materialisation. The variables of the process are related to the designer, and the constants are associated with the material.

Goal construction refers to the intuitive, reflective, skilful or conscious study and evaluation of possibilities of application for existing material in a new context. This step also anticipates design adaptations at the manufacturing stage. Consequently, goal establishment may continue throughout development and eventually overlap with materialisation when redesign is required. Materialisation, on the contrary, can only happen if goal construction is completed.

Cost is not the greatest concern when dealing with ROD, but time and space are significant and directly proportional factors. The more time the acting agent takes to complete ROD; the more space is needed for storage, both physically and mentally. Whenever a material for ROD is saved for future projects, the chances of a successful ROD process decrease.

This attitude, which is incredibly common, emerges from designers' first contact with the resource when they notice that the material is interesting and might be useful for a later project. In some cases, architects often realise that the amount of material readily available is not enough for a prospective project and that more time for collection or harvesting is necessary. This very beginning stage is determinant. Comprehending this factor may cause designers to consider time constraints and material storage as the first major factors for discontinuance of a latent ROD proposal. In fact, material that is saved for later is more likely of being overlooked or forgotten when the appropriate time arrives because no means were provided for easy access to material information.

The scale envisaged for ROD may influence primary concerns about the proposal performance. When the designer is considering a small-scale proposal, the central focus

is typically on the finish, appropriate connections and their influence in finishing. Conversely, for large-scale projects, the principal concerns tend to be structural or in regard to transportation. Those apparently logical observations early in the design process may represent a potential interference in the efficiency of ROD.

Designers have identified different strategies to connect with the material in early stages of ROD. However, some patterns exist in terms of how they tend to manipulate and visualise the material during these beginning stages. When required to create a proposal involving plastic caps that were readily available to be touched, carried, manipulated and experimented with, the designers' first instinct was to grab a bunch of lids and observe them while twisting, pressing and composing groups geometrically. The second drive was to try to find patterns among the pieces. Most designers separated the caps into similar colours and sizes.

Those early stages of ROD are mostly characterised by listening to the material. At this stage, designers gather information about the resource to be applied and materiality is a constant in the project. Therefore, quality and depth of information depend on variables engaged in the process. This initial phase initiates at first sight and through opportunities to touch and manipulate the material onsite. When it comes to mentally building and handling material that is inaccessible because of scale or location, the designer focuses on possible means of visualisation, interaction and manipulation, which may be either physical or virtual. After scanning the pieces individually, designers will attempt to progress to the simulation of compositions within groups of pieces and only then address concerns about availability, dimensions, conditions and intrinsic properties.

Information and learning have shown to be determinant, including detailed research on material amount and properties, considering behaviour upon specific circumstances (i.e. exposure to water or heat, flexibility, resistance to compression and traction). Moreover, learning should comprise a comprehensive analysis of condition, geometry and composition, including investigation of form, regularity, symmetry, detachability, homogeneity and composition factors. The three projects – reflective, intuitive and skilful rematerial interactions – provided evidence about how the lack of exploration of material information might compromise the results, as well as the lack of knowledge about how to transfer, connect and apply this information throughout the four phases of ROD.

Reflective rematerial interaction with the architects indicated a direct tendency to search for precedents for new design solutions, and this search was immediate and

comprehensive through the Internet. The web search was shown to be an essential design assistant throughout the development of ROD proposals and should not be disregarded as an important strategy for modern practice. Browsing is a frequent step for ideation of functionality, aesthetic material information and learning and recognition of manufacture processes.

Those results represent major changes in the architectural field for aims and products but particularly in the process of creation. Digital tools are now accessed routinely and have become fundamental gears supporting the design process. Concomitantly, easy access to information has influenced means of information collection and analysis.

It became clear that construction of accurate and detailed documentation that absorbs information from the phases of ROD will enable more realistic expectations, increase the viability of an upcycling proposal and avoid (or minimise) redesign during the delivery stage. To accomplish these goals, digital tools must be adopted with a full awareness of the complexity of dealing with rematerial and the consideration of specificities such as irregularity and heterogeneity.

Participants of material interactions have no (direct) need to upcycle. This means that they might just go somewhere to purchase brand new materials, objects, elements and structures. Some proposals create social or community profiles, correlating the practice to social or sustainable causes by reducing disposal, expenditure of feedstock and consumerism. Surprisingly, these motivators are not clearly attached to most proposals, which mainly focus on materiality exploration to discover, enhance and revive the hidden beauty of existing goods.

## 8.2 Contributions of the Thesis

This thesis has identified important aspects related to process, material and designer regarding the knowledge, tactics and tools currently adopted for problem-solving in ROD. These factors relate to the process variables that can be managed by the designer and the constants commonly associated with the material.

The framework and the reference model developed herein formalised the structure of rematerial interactions with these identified factors and addressed detailed implications for the awareness, effectiveness and efficiency of the process. Based on the findings, these implications are assumed to be related to the lack of a controlled approach for managing

relevant ROD information (constants and variables) to enable directed research and ideation, continuous updates of data, appropriate communication, transfer, and storage with prompt accessibility.

Based on the understanding developed in this thesis, the investigation concludes with the establishment of support through the prescriptive study, which frames the conditions for conscious rematerial interactions and introduces an applicable instrument for direct support in the practice. In conscious ROD, continuous consideration of data regarding crucial ROD aspects (variables, constants and decisions) will enable *consciousness* of the process by facilitating informed decisions, *efficiency* thru lessening redesigns and streamlining the process, and *effectiveness* in increasing the chances for positive outcomes, even when the rematerial is being saved for later.

Given this context, the hypothesis that understanding rematerial interactions would enable the development of a model towards more conscious, effective and efficient rematerial interactions has been endorsed. Summarising, the study configured an original framework for rematerial-oriented design that determined activity terminology, provided comprehensive structures and categorised different approaches according to designers' perspectives and experience with design for upcycling. This study identified the weaknesses in how intuitive rematerial interactions are carried out and verified the improvability of the process through means of connecting and considering appropriate rematerial information.

### 8.3 Constraints on the Results

There were a few constraints that limited the scope of the results reported in this study. The first relates to the sample size and comprehensiveness of design activities in the projects designed for empirical data generation. Ideally, the performance of both novice designers and experienced designers should be investigated during the four ROD stages (discovery, definition, development and delivery). Also, more expert designers from diverse geographical locations could reveal new and interesting materiality approaches. However, time, resources and participants' availability constrained this aspect of the investigation.

The second potential limitation in the results was the number and nature of design tasks required in the reflective rematerial interaction, which comprised two design tasks completed on the same day and in the same survey. Results showed that participants put

much more effort into the first task (proposal with plastic lids). Hypothetically, this variation could be attributed to two factors: (a) as the architects completed the first task, they became tired and intended to quickly finish the exercise; and (b) participants were more excited about the proposal in which they could experience materiality – that is, they could manipulate the material (in this case, the lids). This occurrence could be investigated further through a project design in which participants are not submitted to two tasks at once but rather receive randomly distributed tasks (some perform one type, whereas others complete the second task). Alternatively, participants could be provided with a means for manipulating the rails (i.e. miniature plastic rail models).

The next two constraints refer to the methods supported by NVivo. The word frequency queries run in the nodes enabled the listing of more frequent words containing four or more letters. However, some reference codes were compound expressions instead of single words. For that reason, each word needed to be checked individually in the summary list generated from the query.

Additionally, some contradictions existed between computer activities and parity of actions. In this study, predominant activities within a timeframe were tracked. However, when tracking computer activities, the ActivTrak agent took some time to recognise the transition from a recent activity to idle time if the computer was not in use. This meant that the agent would only detect idle activity after a considerable amount of time with no use.

## 8.4 Future Directions

The future directions of this research involve the accomplishment of the last stage of DRM suggested by Blessing and Chakrabarti (2009), Descriptive Study II (DS-II), which will explore the effect of the support and its capacity to accomplish the desired situation. Therefore, further investigation is needed to refine REMIM and test its operability for inputting new and updated information within real design scenarios. A prototype of the instrument is needed to test a framework upon which to build a computer-based software to enable conscious rematerial interactions and, thus, improve design outcomes based on the architectural upcycling process addressed in this thesis.

As an integrated system, additional digital features could be added to REMIM for the input and output of material information to empower and automate rematerial interaction during conscious ROD. These components include but are not limited to the following:

- A visual database for rematerial location, tracking and availability within local and regional contexts;
- Rematerial scanning, 3D printing and rapid prototyping to facilitate digital manipulation and formal exploration
- Comparisons of object similarity based on Kernel machine algorithm (Schölkopf, Burges, & Smola, 1999; Schölkopf & Smola, 2002) to explore formal similarity of rematerial and enhance goal construction
- Import of material performance and properties information through interface with software for material selection, such as Granta CES Selector (Granta Design, 2017)
- Digital model deliverables in CAD and BIM formats and data reports accessible through BIM platforms.

## 8.5 Summary

Chapter 8 closed this investigation with reflections about factors related to rematerial interactions. It delineates the main contributions of the thesis and lists some constraints, while identifies opportunities for future research.

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**PART IV**  
**Appendices**

# Appendix A

## Reflective Rematerial Interaction

This appendix contains a compilation of the design exercises executed by the architects and their responses and the analysis made. Their names are omitted for privacy purposes. Following the survey, four spreadsheets are presented containing, respectively, the ‘classification sheets’ from computer activities and description of the participants, the summary of participants’ activities, Data details and word-clouds analysis.

The NVivo project file containing raw sources, node structure and classifications related to the project is available in a shared folder hosted by Dropbox service, accessible through the link below. It is necessary to have NVivo software installed in the computer to open the files.

<https://www.dropbox.com/sh/vpy0r00y657x74o/AAC5t2XVY9oev7mian0x9S0da?dl=0>

### **A1. The design task and results**

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Rematerial-oriented Design survey

Introduction and instructions

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Rematerial-oriented is a new approach for design upcycling whereas the resource available (usually reject material) is the starting point for the process. In the beginning of the process, the designer has not found out what the material/element/structure will become until the design starts and the first ideas are built.

“...to upcycle something is simply to re-purpose something that would otherwise be considered waste & to 'up' its value and quality by doing so. The difference between upcycling and recycling is that when you recycle something - generally the components are broken down and the result is an item of lesser quality e.g.: recycled paper.” (Lynn Haughton).

This activity is basically a means-oriented design exercise. Although any ordinary person may be able to make it, architects have more developed spatial vision capability, they have their own tactics for pumping up creativity and further knowledge on how documenting ideas and dealing with specific issues.

You have up to 3 hours to complete the exercise. Read all the questions before starting. If you choose to answer the questions only through drawings, sketches or models, you may leave the spaces blank. Please keep or save all text files, relevant images, drawings, sketches or models made during this time. They will be collected at the end of the session. It is advisable to keep long answers safe (i.e. using word) as this online survey do not allow you to save your answers before you submit them.

Do not be disappointed if you are not able to complete your thoughts or proposals or if you are not happy with your ideas. The time is short for a complete design proposal and our focus is on the process of the initial thinking in means-oriented design, not on the outcome.

1) About your qualification: area / obtaining year / country

Responses:

1. Master of Landscape Architecture/ 2006/ Poland
2. Master of Architecture/2013/Australia
3. Architect and urbanist, 1976, Brazil
4. Architecture/2013/Australia
5. Architecture and Urban Planner/2004/Brazil
6. Architecture/2012/Australia
7. Architecture/2011/Australia
8. Architecture/2013/Australia
9. Diploma in Architecture/1991/India
10. Architecture and Urban Design / 2007/ Brazil

2) How far are you familiarized with upcycling? You may select more than one answer.

		<b>Response (%) Responses</b>
I have been practicing for both professional and personal purposes.		18.18    2
I have been practicing only for professional purposes.		0.00    0
I have been practicing only for personal purposes.		45.45    5
I have tried a couple of times but I am actually not very good at.		9.09    1
I have great ideas, but not always (or never) complete my projects		18.18    2
I am not familiarized at all.		9.09    1
<b>Answered Question</b>		<b>10</b>

3) Create a design proposal for upcycling the lids provided. Take your time to make your decisions on what to propose and how it would be built. Feel free to analyse and manipulate the material and ask further questions about it. Detail your proposal as many as possible. You may describe your proposal using either text or drawings/sketches/models or both.

Responses:

1. A design proposal for a set of division walls at a playground (please see sketches attached) Proposed building materials: plastic lids (different sizes and colours), recycled wooden slats, fishing line. Three temporary division walls are required to be installed at an existing playground. Size of the proposed walls: (Height x Length) 135x200cm How is it going to be made? The frames will be made out of recycled wooden slats. The infill will be made out of plastic lids connected using fishing line. The patterns will depict elements from natural environment – leaves, stones, trees, the sky and the sun, earth profile etc. The walls will be resistant to the changing weather and will withstand even strong winds. The reasoning behind using upcycled materials: - It teaches people from a very young age about recycling, how to use creativity to incorporate existing objects (often seen as useless) into building or artistic project. - People at a young age are exposed to alternative ideas which may influence and broaden their own imagination and further lead to a development of their own recycling ideas.
2. I propose a light fixture made out of flat wide bottle caps. Connected using cable ties threaded through pre-drilled holes. see images attached.
3. My intention was to build a light structure using the materials provided. It resulted in a pyramidal form with 'eaves' that could refer to a shading structure to protect from the sun. The structure was created using the lids as bases and connectors. The structure's design started trying the materials in a playful manner and discovering different uses for them.
4. Most lids use HDPE plastic which can be melted down into flat sections using a sandwich press. The thickness, colour and shape of the material can be experimented with using material tests. The flattened sections of plastic could be cut into tiles and used as a cladding material. In this immediate site one potential use for this material could be to clad the entire interior of the

room - walls, floors, ceiling. This would completely alter the spatial qualities of the site. Then the site could be used as a gallery for other sculptures and artworks developed using the same material. One example might be sculptures similar to the outsider art of M. Ringo White.

5. Notes about the lids/impressions: Variable heights All of them: screws, texture around Most of them have smooth top It is not worth to deconstruct/recycle the lids (I believe they should be applied in their original rounded form) Projects based on repetition Fishing line for connection? The first step of my proposal was to figure out that the lids would work together creating a repetitive pattern. As they could be connected side to side (tangent to tangent) they could be transformed into beautiful and interesting interior pieces and even some panels for architecture composing. The second step was to create an easy connection that worked to keep them together. One issue to consider is that the screws inside (that could be used to slot the connection) have variable heights. Those joints could be printed in plastic or made off holes, screws and bolts (this option would make the piece heavy, so maybe is not appropriate). The perfect joint would be made out of reclaimed stuff but more time is needed to develop a connection for jointing the lids. As the lids have good stability when under pressure on their top and guided through a recent personal need, I would apply the lids to build a colorful mat. If the joints also allow, being a plastic mat that could be used outside in a varanda or a garden. Various sizes and colors would be used to construct the mat (see sketches). I haven't checked if there is enough lids for my proposal or if I had to save some more.
6. The lids can be used to provide vibrant wayfinding assistance in either educational facilities or public health facilities. We can create patterned walls or floors by embedding them in concrete and sealing over with clear resin. There is also opportunity to use the patterns to form mosaic pictures, because there is a wide variety of colours and shapes available. (See examples on sketches)
7. The intent was to create a screen with different apertures, governed by the connections - all diagonal connections would be triple 'stringed', all straight connections would be single. All the apertures would be determined by the placement on a grid.

8. Observations: 1. The lids have provided us with a variety of characteristics that are quite consistent throughout, these are as follow, a. They all come in 4 distinct size b. A variety of colours c. A variety of textures d. A Variety of shapes (Different radiuses and in turn different turning circles.)e. The lids operate as gears where one put side by side with the other can create a turning motion. The dents on the sides of the lids contribute to this attribute of the lids. 2. The light emitted from each of the lids gives provides with a funky colour that is part of the characteristics of the lid. Hence the colour of each emitted light is different. 3. The fact that each lid comes in a different shape also changes the way each colour is emitted. Hence the form of each emitted light is different. 4. Since the light emitted is opaque, it is not see through. 5. By lighting a torch behind each of the lids, they light up, illuminating the inside of the lid and emitting a small light on the outside. Challenges 1. How much light is required to illuminate the lid and its outside environment or is the light only providing a colourful glow. 2. Is this glow a property of the thickness of the lids or is it a property of the chemical used in the colour. 3. What sort of light and what colours of light can be best utilized. 4. Can the colours be mixed? Design a) Utilizing the gearing system on the edges of the lids, the design is to create a dynamic texture that uses the colours of the lids to illuminate different colours as light has been shone through them. As there are different sizes of lids, they can be stacked vertically using a rod where the larger caps sit at the bottom since they have the largest turning circle and the smaller ones on the top. As the gearing system starts its motion the bigger lids turn and move the smaller lids on top of them along with it. b) This design creates a dynamic moving lighting fixture that produces different colours and ambiances based on the mixture of the colours of lids, shapes of their sizes and their thicknesses as well as combination of different colours as well as individual ones. c) This design creates a dynamic lighting fixture that utilizes all the observed properties of the light based on assumptions made that were raised from the challenges. d) A powered machine is required to create a turning basis for the bottom lids and the light and the fixture itself shall be able to maintain itself throughout.
9. Existing characters. First impression: plastic, hard, light in weight, circular cylindrical shapes, and bright colours. Has structural mass and could support itself. Possible reuse, taking into consideration existing characteristics. As it is: use different colours to represent functions to help

with initial bubble diagram for space location and relationship between functions and site. Able to use them to explore space organisation options. Practical uses: door stops, table legs base, door knobs? Design reuse: art work, glue them together to become a lampshade, decorative pins, rings Jewelry. Minor changes: physically transfer the characteristic into flatter surface, a combination of colours melted into one surface, as a cladding As it is or a combination with other materials to create an object. Light fitting, fruit bowl.

10. Please look at the word document attached.

3) Create a design proposal for upcycling a pile of rails. The file below contains the section of the pieces and other information. Sizes vary from 3 to 5 meters. Take your time to make your decisions on what to propose and how it would be built. Feel free to analyse the material and ask further questions about it. Detail as many as possible. You may describe your proposal using either text or drawings/sketches/ models or both.

Responses:

1. Design proposal No 2: pile of rails A proposal to use upcycled rails to build a pedestrian bridge. Proposed building materials: 2-4 rails 5m long, 3 rails 3m long. The rails will be used as beams bearing the wooden decking. Additionally, 3 rails (cut into 1.5m pieces) can be used to build handrails.
2. I propose the design of an architectural pavilion made of pre-cut rail channels welded together on site using custom steel brackets. See images.
3. The railings could be used to build porticos, using the 3.00m pieces as columns and the 5.00m ones as architraves to build modular structures for different uses, in public spaces or landscape projects.
4. Given the unlimited scope of the brief I decided to stack 2000 sections of rail within a 50m cube. Sections could be welded together. Structure would need to be resolved to make sure it could stand up safely.
5. The first and obvious thought for this project was to use the rails as structural pieces for spaces, especially pillars. Its elongated form and heaviness make us think they would be more appropriate if used with a structural function. Another option would be to build landscape furniture or even interior furniture. I would propose a set of benches and table legs for these rails,

together with another material, maybe pallets or glass to be the table top. (please see the sketches attached). I would be interesting to use steel plates to connect pieces together – external joint – as maybe it isn't worth modifying original pieces to slot them (internal joint, not sure about the name).

6. The rail pieces can be used for outdoor public furniture installation as it is really heavy and will not be subjected to much movement. They can form the beam structures for horizontal sitting surfaces, by having them cast into concrete piers. The existing bolt holes can be used for any vertical connections.
7. Sliding door rail Columns linked together by a web structure Slicing the rail – then geometrically arrange them into a screen.
8. The structural properties of the rail proves that the material is hard to move around as is very heavy and requires heavy machinery to cut. As each meter weights about 60kg smaller segments such as 30cm pieces would weight around 20kg each piece allowing for extra weights. This means that if the rail was to be cut down to smaller pieces it would be a lot more manageable. As the rail is a heavy material and is used industrially quite often, it is often unforeseen the shape that it withholds. The area between the head and foot where the web sits is connected to its adjacent parts through a smooth curve. This smooth curve can replicate the size of a bottle. Wine bottle sizes come in a variety of 70-90mm circumferences and as the web size of the rail is 90 mm this gives around 20 mm of movement. If the 30 cm segments of the rail can be cut off and bolted to a platform, it can make for quite an outstanding wine holder and provide a genuine brutalist connection to the structural integrity of an architecture that includes similar materials in its construction. The texture and the heaviness of this material creates a balance with its purpose and could prove quite substantial in its use.
9. Existing characters: First impression: metal, hard, specific shape, and dark colour could be rusty. Has structural mass and will support itself. Originally designed to support heavy rail carriages travelling at speed. Designed to be supported on ground, material composition might not be designed to be used as structural support, as beams supported at either ends only or could be. Not sure of its tensile capability, can it support load on point, vertically not horizontally? Heavy, Weight could it be used to advantage. Possible reuse, taking into consideration existing characteristics. Existing structural

members with similar weight. Universal beams (I Beam): UNIVERSAL BEAM 410mm X 59.7kg/m 59.7 weight per m2, 1.49 external surface area per meter, 406 depth of section, 178 flange width, 12.8 flange width, 7.8 web thickness, 381 depth between flanges. UNIVERSAL COLUMN 200mm X 59.5kg/m 59.5 7 weight per m2, 1.22 external surface area per meter, 210 depth of section 205 flange width 14.2 flange width 9.3 web thickness 181 depth between flanges. 155 ct 59 column Tee or Beam Tee (cut from a UC section) has similar weight. As it is: structural support replacement to Universal Column or beam. As it is: Structural retaining wall piles. As it is: floor joist additional advantage house/ superstructure could move open and close. Material mass, over 60% Carbon, melt it down for material. Practical use: landscape sculpture, garden seat element, as in Tanner Springs Park, Portland, OR. Cut into small pieces can be used as hangers, wine racks, door handles, weights. free standing stair support.

10. Please look at the word document attached.

4) What item(s) may configure an obstacle to implement your proposals?

		Response (%)	Responses
No obstacle is foreseen. The proposal is quite solid.		0.00	0
Unsure		0.00	0
Different sizes among the pieces		10.87	5
Appropriate joinery/connections		13.04	6
Appropriate tools		15.22	7
Skills/ Labour		15.22	7
Transportation		15.22	7
Health and safety		6.52	3
Durability		2.17	1
Material availability		8.70	4
Unexpected material condition prior			

5) If you have foreseen obstacles other than listed, please describe below.

Responses:

1. No response.
2. No response.
3. No response.
4. Budget for the project.
5. Lack of time to develop details for the proposals.
6. Willingness of end users to accept alternative materials.
7. Not having a brief to design to made the application/manipulation of the rail more difficult.
8. the inconsistency within the thicknesses of the bottle lids.

9. to be able to use as structural members it has to be approved to be suitable. being so heavy transportation will be an issue, will require lifting mechanism.

10. Perhaps I would need a structural engineer as a consultant to work with the used rails. Other insights written on word document attached.

## A2. Classification sheets – Protocol

	Actions	Actions 0-15 min	Actions 15-30 min	Actions 30-45 min	Actions 45-60 min	Actions 0-15 min (2)	Actions 15-30 min (2)
Nodes\Participants\ID (X)\ID (X) Protocol	D (01) Protocol	on computer	on computer	on computer	sketching/drawing	sketching/drawing	on computer
	D (02) Protocol	manipulating	on computer	sketching/drawing	pause	on computer	sketching/drawing
	D (03) Protocol	manipulating	modelling	modelling	modelling	modelling	on computer
	D (04) Protocol	on computer	manipulating	on computer	sketching/drawing	modelling	on computer
	D (05) Protocol	manipulating	sketching/drawing	sketching/drawing	on computer	sketching/drawing	on computer
	D (06) Protocol	on computer	manipulating	on computer	on computer	on computer	pause
	D (07) Protocol	modelling	modelling	modelling	modelling	sketching/drawing	modelling
	D (08) Protocol	on computer	on computer	sketching/drawing	on computer	pause	on computer
	D (09) Protocol	on computer	manipulating	modelling	modelling	on computer	sketching/drawing
	D (10) Protocol	on computer	manipulating	on computer	sketching/drawing	on computer	on computer
Nodes\Participants\ID (X)\ID (X) Protocol	Computer activity	Computer Act 0-15 min	Computer Act 15-30 min	Computer Act 30-45 min	Computer Act 45-60 min	Computer Act 0-15 min (2)	Computer Act 15-30 min (2)
	D (01) Protocol	Survey	web search	web search	Text editing	web search	web search
	D (02) Protocol	Survey	web search	Digital tool	Digital tool	web search	Digital tool
	D (03) Protocol	Survey	Text editing	Idle	Idle	Idle	Text editing
	D (04) Protocol	Survey	Idle	web search	Digital tool	Digital tool	web search
	D (05) Protocol	Survey	Idle	web search	Text editing	web search	Survey
	D (06) Protocol	Survey	Digital tool	web search	web search	web search	Text editing
	D (07) Protocol	Survey	Idle	Idle	web search	Idle	Idle
	D (08) Protocol	Survey	web search	web search	web search	Digital tool	Digital tool
	D (09) Protocol	Survey	Text editing	Idle	idle	web search	Idle
D (10) Protocol	Survey	web search	web search	Digital tool	Digital tool	web search	
Nodes\Participants\ID (X)\ID (X) Protocol	Actions	Actions 30-45 min (2)	Actions 45-60 min (2)	Actions 0-15 min (3)	Actions 15-30 min (3)	Actions 30-45 min (3)	Actions 45-60 min (3)
	D (01) Protocol	sketching/drawing	on computer	EXERCISE COMPLETE	EXERCISE COMPLETE	EXERCISE COMPLETE	EXERCISE COMPLETE
	D (02) Protocol	on computer	EXERCISE COMPLETE	EXERCISE COMPLETE	EXERCISE COMPLETE	EXERCISE COMPLETE	EXERCISE COMPLETE
	D (03) Protocol	on computer	EXERCISE COMPLETE	EXERCISE COMPLETE	EXERCISE COMPLETE	EXERCISE COMPLETE	EXERCISE COMPLETE
	D (04) Protocol	on computer	sketching/drawing	on computer	on computer	on computer	on computer
	D (05) Protocol	EXERCISE COMPLETE	EXERCISE COMPLETE				
	D (06) Protocol	on computer	on computer	on computer	on computer	pause	on computer
	D (07) Protocol	sketching/drawing	on computer	EXERCISE COMPLETE	EXERCISE COMPLETE	EXERCISE COMPLETE	EXERCISE COMPLETE
	D (08) Protocol	on computer	on computer	on computer	on computer	EXERCISE COMPLETE	EXERCISE COMPLETE
	D (09) Protocol	on computer	modelling	on computer	on computer	EXERCISE COMPLETE	EXERCISE COMPLETE
D (10) Protocol	on computer	on computer	on computer	EXERCISE COMPLETE	EXERCISE COMPLETE	EXERCISE COMPLETE	
Nodes\Participants\ID (X)\ID (X) Protocol	Computer activity	Computer Act 30-45 (2)	Computer Act 45-60 (2)	Computer Act 0-15 (3)	Computer Act 15-30 (3)	Computer Act 30-45 (3)	Computer Act 45-60 min (3)
	D (01) Protocol	web search	Survey	EXERCISE COMPLETE	EXERCISE COMPLETE	EXERCISE COMPLETE	EXERCISE COMPLETE
	D (02) Protocol	Survey	EXERCISE COMPLETE	EXERCISE COMPLETE	EXERCISE COMPLETE	EXERCISE COMPLETE	EXERCISE COMPLETE
	D (03) Protocol	Survey	EXERCISE COMPLETE	EXERCISE COMPLETE	EXERCISE COMPLETE	EXERCISE COMPLETE	EXERCISE COMPLETE
	D (04) Protocol	web search	Text editing	web search	Digital tool	Text editing	Survey
	D (05) Protocol	EXERCISE COMPLETE	EXERCISE COMPLETE				
	D (06) Protocol	web search	web search	Digital tool	Text editing	Idle	Survey
	D (07) Protocol	Idle	Survey	EXERCISE COMPLETE	EXERCISE COMPLETE	EXERCISE COMPLETE	EXERCISE COMPLETE
	D (08) Protocol	Digital tool	web search	Digital tool	Survey	EXERCISE COMPLETE	EXERCISE COMPLETE
	D (09) Protocol	web search	Idle	Text editing	Survey	EXERCISE COMPLETE	EXERCISE COMPLETE
D (10) Protocol	Digital tool	Text editing	Survey	EXERCISE COMPLETE	EXERCISE COMPLETE	EXERCISE COMPLETE	
OBS.	For actions, it was considered the predominant activity within that timeframe. About the computer activities, the Activitrak agent take some time to recognise the transition from a recent activity to idle time.						

**A3. Classification sheets – Participants’ individual description, summary of activities and means used for communicating their proposals.**

Description	Qualification	Country	Year obtained	Upcycle practice	Lids proposal description	Rails proposal description
D(01)	Landscape Architect	Poland	2006	Quitter	Text and drawings	Text and drawings
D(02)	Architect	Australia	2013	Unfamiliar	Drawings and digital model	Drawings and digital model
D(03)	Architect	Australia	2011	Home	Text, drawings and physical model	Text and drawings
D(04)	Architect and Urban Planner	Brazil	2004	Field/home and quitter	Text and drawings	Text and drawings
D(05)	Architect	Australia	2011	Home	Text and drawings	Text and drawings
D(06)	Architect and Urban Planner	Brazil	2007	Home	Text and web images	Text and web images
D(07)	Architect and Urban Planner	Brazil	1976	Home	Text, drawings and physical model	Text, drawings and model
D(08)	Architect	Australia	2013	Flairless	Text and digital model	Text and digital model
D(09)	Architect	India	1991	Field/home	Text, drawings and physical model	Text and drawings
D(10)	Architect	Australia	2012	Home	Text and drawings	Text and digital model
	Obstacles foreseen	Summary of individual activity				
D(01)	4	Most of the time on the computer doing web search. Some text editing and drawings. Spent 1:45/2:00 on the task.				
D(02)	3, 4, 5, 6, 7, 8, 9, 10, 11	Intercalated web search with Digital tool usage (Rhinceros). Some sketches and drawings. Spent 1:30/1:45 on the task				
D(03)	3, 5	Half of the time modelling and half text editing, preparing the description of the proposals. Spent 1:30/1:45 on the task				
D(04)	3, 4, 5, 6, 7, 10	Intercalated web search with Digital tool usage (Sketch up). Some text editing, sketches and drawings. Spent 3:00 on the task				
D(05)	12	Intercalated sketching and drawing with some web search. Spent only 1:15/1:30 on the task				
D(06)	5, 6, 7, 12	Most of the time doing web search. Quick use of a digital tool. Some text editing and no drawings. Spent 2:45/3:00 on the task.				
D(07)	4, 5, 6, 7	Spent most of the time modelling. Minimum web search. Spent 1:45/2:00 on the task				
D(08)	4, 5, 6, 7, 8, 10, 11, 12	Initial half of the time doing web search and then using Photoshop and Rhinceros. Minimum sketching. Spent 2:15/2:30 on the task				
D(09)	3, 5, 6, 7, 11	Diversified activities. Web search, text editing, sketching/drawing and physical modelling. Spent 2:15/2:30 on the task				
D(10)	3, 4, 5, 6, 7, 10, 11	Intercalated web search with Digital tool usage (Archicad) Some text editing, sketches and drawings. Spent 2:00/2:15 on the task				

#### A4. Summary of general participants' activities

Observations: Actions + Computer Activities			
15 min intervals		1 hour intervals	
00-15 min	During this initial interval, the participants are reading the information sheet provided and the online survey. Some of them take some time manipulating the lids	In this first hour there seems to be an intercalation of activities between goal construction (building of ideas and research of precedents) and materialization. Intense interpolation of web search with sketching and drawing to define and develop ideas on paper. Only two participants keep executing one predominant activity during this time. This first hour is also characterised by material manipulation, experimentation and physical modelling.	1st hour
15-30 min	Now others spend time manipulating the lids. Only two participants have not touched them at any time. At this moment, seven out of ten start some computer activity and those who are not using the computer are either tridimensionally thinking through material experimentation (physical modelling) or doing sketches or drawings.		
30-45 min	Only three of them had no computer activity tracked. The majority has performed web searches and parallel activities as drawing and modelling is also commonly performed at this stage.		
45-60 min	Nine participants show some computer activity during this interval. One third is mainly on computer, one third is modelling and the other third is drawing		
00-15 min	Only two had no computer activity tracked at this interval. Web searches are performed in parallel with activities as drawing and modelling.	Half participants complete the task within the second hour. Four participants did some type of physical modelling using the material provided at some stage and only two have performed no sketch or drawing during the whole experiment.	2nd hour
15-30 min	One exercise completed. Eight computers show activity during this time with text editing, digital modelling and web search.		
30-45 min	Three exercises completed in total. 7 out of 9 predominantly on computer and 2 sketching/drawing. Just one participant had no computer activity.		
45-60 min	6 out of 7 predominantly on computer and 1 sketching/drawing. Just one participant had no computer activity. Two more finish the survey during this time interval.		
00-15 min	All four participants working on computer. Edition of digital models and text for submitting the survey	The last hour is characterised by materialization of ideas. Although the remaining participants (5 out of 10) are all predominantly working on their computers, web search is rare or null (just one occurrence). Registered activities include digital tools usage and text editing for finalising the descriptions of the proposals on the survey.	3rd hour
15-30 min	All five participants working on computer, but just one web search tracked. Edition of digital models and text for submitting the survey		
30-45 min	Two participants to complete the survey. One pause and one editing the proposals		
45-60 min	Last two surveys submitted		
Data retrieved from classification sheet in Nvivo (computer activities from Activtrak and actions from videos)			

## A5. Data details and word-clouds analysis

Parent	Label	Observation	Child	LABE	Observation
Computer Activity	WQA	The word query performed in the Parent Node 'Computer Activity' demonstrate the leading application of the computers towards precedents of how those materials could possibly be reused or repurposed.	Applications	WQ1	The most used application was Microsoft Word, followed by Archicad, Rhinoceros and Sketch up (same count). Then appears Autodesk 3D Max, Adobe, Evernote and Photoshop. It is interesting to note, however, that some applications for 3D computer graphics and computer-aided design (CAD) -Rhinoceros, Archicad and Sketch up - were applied in such a short amount of time.
			Key-words search	WQ2	The leading word for web search was plastic, and not always in conjunction with the word lids, the second most frequent. Most searched words in sequence relates to original elements (plastic, lids, rail, bottle, train, caps), followed by process titles (recycle or recycled, ways, upcycling). Then the words which appear at least twice are mixed (railroad, furniture, made, reuse, design, ideas, etc.).
			Websites	WQ3	Google search was shown by far the most used website used. The references point that all participants employed the web search tool at least once and It was the guide for all other websites. Then appears Pinterest, forums, you tube, Yahoo Answers, Wikipedia and other varieties (care, living, translate, science, etc.).
Material Information	WQB	In general, superficial consideration of material information in this early stage of ROD. Although most designers did not described their conceptualization, it made clear how common is to search for precedents available on the internet for fomenting and consolidating your own ideas.	Concept / precedents	WQ4	Word frequency was not appropriate for analysing the node related to 'Concept development and Precedents'. This node highlighted evidences found in the surveys where participants tried to conceptualize their reasoning and justify choices and web searches. As only words were not significant in correlating the architects thoughts, all references coded for that node were consulted for a further picture. Six out of 10 participants made reference of contextualization, with relevant indication of the social pattern of the upcycling practice. One third of them related recycling and reusing to children or people from young age and four connects the upcycling activity to community, urban or landscape projects.
			Connections	WQ5	The proposed connections and joints cited within the surveys include lids, fishing lines, cable ties, holes, concrete, metal structure and steel plates, screws, welding, bolt and brackets. Eight out of ten participants described in the surveys possible connections to solve their proposals. However, none has added detailed information about them within their models or drawings.
			Material Addition	WQ6	Four proposals from three participants considered the addition or combination of the lids and rails with other materials, apart form adding others as connectors. It was suggested recycled wooden slats, pallets and glass.
			Material availability	WQ7	Two designers have shown any concern about material availability. One suggested collection points of lids in train stations and schools. Another has pointed that it should be a challenge to collect enough for the projects. In the survey, it was stated that they had a 'pile of rails' available for their projects, but no one questioned or estimated how many rails this pile was compound.
			Material properties	WQ8	Material properties were investigated by the architects most superficially. Sixty percent has shown any concern on the properties of the materials to be projected. For the vast majority, only conditions as colour, size, shape weight (whether the material was heavy or light) were slightly considered. Two participants made more comprehensive researches on properties and both considered that research in their proposals.
Proposal A	WQC		Multiple	WQ9	Proposals for the lids include: (interior) bubble diagram (to be used as a flow diagram), door stops and knobs, table legs base, lampshade and light fitting and light fixture, jewellery, cladding, fruit bowl, seat, toy, mat. (urban/architectural) mosaic pictures, tunnel, street art, wall panel and playground walls, screen, shading structure, way find assistance. Interior artefacts related to light fitting (fixture, lamp, table lamp, light) appeared frequently. Cladding was suggested twice and architectural walls, panels, screens were also commonly cited.
			Specific solution	WQ10	
Proposal B	WQD		Multiple	WQ11	Proposals for the rails include: (interior) wine rack, door handle, furniture, (urban or architectural) landscape pieces or sculpture, column, outdoor furniture, structural element, sliding door element, porticos. Furniture and structural elements were the most considered proposals.
			Specific solution	WQ12	

A6. Word clouds



Figure 1. WQ1



Figure 2. WQ2



Figure 3. WQ3



Figure 4. WQ4



Figure 5. WQ5



Figure 6. WQ6



Figure 7. WQ7



Figure 8. WQ8





## **A7. Case nodes: Data details**

The following data comprise of the references coded in NVIVO within the Case nodes 'Data details'. As stated in Chapter 4, it aimed at exploring the sources (Survey, Activity Logs, Screenshots and Notes) added to NVivo to mark relevant words, terms and definitions used by the participants to describe their proposals and generated by the automated tools applied for the collection of activity information throughout the experiment. Four parent nodes were created: Computer Activity, Material Information, Proposal A and Proposal B.

### **Name: Nodes\\Data details\\Computer activity**

<Internals\\D (01)\\Screenshots \_ ActivTrak> - § 13 references coded [1.90% Coverage]

Reference 1 - 0.14% Coverage

PLASTIC LEADS WALL

Reference 2 - 0.10% Coverage

GOOGLE SEARCH

Reference 3 - 0.16% Coverage

UPCYCLE WOODEN SLATS

Reference 4 - 0.03% Coverage

WORD

Reference 5 - 0.22% Coverage

HOW TO GROW MOSS ON PLASTIC

Reference 6 - 0.21% Coverage

DOES MOSS GROW ON PLASTIC?

Reference 7 - 0.18% Coverage

THE PLANTED TANK FORUM

Reference 8 - 0.15% Coverage

UPCYCLING RAIL TIES

Reference 9 - 0.16% Coverage

UPCYCLING RAIL LINES

Reference 10 - 0.12% Coverage

UPCYCLING RAILS

Reference 11 - 0.17% Coverage

UPCYCLING TRAIN RAILS

Reference 12 - 0.14% Coverage

RAIL TRAILS REUSED

Reference 13 - 0.10% Coverage

RECYCLED RAIL

<Internals\\D (02)\\Screenshots \_ ActivTrak> - § 4 references coded [0.56% Coverage]

Reference 1 - 0.10% Coverage

GOOGLE SEARCH

Reference 2 - 0.21% Coverage

DESIGNS USING PLASTIC CAPS

Reference 3 - 0.08% Coverage

RHINOCEROS

Reference 4 - 0.17% Coverage

RECYCLED RAILS DESIGN

<Internals\\D (03)\\Screenshots \_ ActivTrak> - § 1 reference coded [0.48% Coverage]

Reference 1 - 0.48% Coverage

Microsoft Word

<Internals\\D (03)\\Screenshots \_ ActivTrak1> - § 3 references coded [0.65% Coverage]

Reference 1 - 0.18% Coverage

TRAIN RAIL

Reference 2 - 0.23% Coverage

GOOGLE SEARCH

Reference 3 - 0.23% Coverage

CUTTIN A RAIL

<Internals\\D (04)\\Screenshots \_ ActivTrak> - § 27 references coded [1.41% Coverage]

Reference 1 - 0.05% Coverage

GRAPHISOFT ARCHICAD

Reference 2 - 0.03% Coverage

MICROSOFT WORD

Reference 3 - 0.02% Coverage

SKETCHUP

Reference 4 - 0.04% Coverage

TRANSLATE GOOGLE

Reference 5 - 0.07% Coverage

RECYCLE LIDS PLASTIC BOTTLES

Reference 6 - 0.03% Coverage

GOOGLE SEARCH

Reference 7 - 0.06% Coverage

TOYS FROM RECYCLED LIDS

Reference 8 - 0.06% Coverage

PROJECTS WITH PLASTIC LIDS

Reference 9 - 0.11% Coverage

PINTEREST: DISCOVER AND SAVE CREATIVE IDEAS

Reference 10 - 0.04% Coverage

CONEXÃO LUSÓFONA

Reference 11 - 0.06% Coverage

EASY WAYS TO GLUE PLASTIC

Reference 12 - 0.02% Coverage

WIKIHOW

Reference 13 - 0.06% Coverage

APARELHO SOLDAR PLÁSTICO

Reference 14 - 0.02% Coverage

## YOUTUBE

Reference 15 - 0.08% Coverage

## HOW TO RECYCLE PLASTIC CAPS & LIDS

Reference 16 - 0.08% Coverage

## HOW TO CONNECT TWO PLASTIC LIDS

Reference 17 - 0.05% Coverage

## SCIENCE EXPERIMENTS

Reference 18 - 0.05% Coverage

## LANDSCAPE FURNITURE

Reference 19 - 0.06% Coverage

## STEEL LANDSCAPE FURNITURE

Reference 20 - 0.05% Coverage

## FURNITURE WITH RAILS

Reference 21 - 0.04% Coverage

## RAIL YARD STUDIOS

Reference 22 - 0.10% Coverage

## 25 WAYS WITH BOTTLE TOPS & PLASTIC CAPS

Reference 23 - 0.03% Coverage

## DOMESBLISSITY

Reference 24 - 0.04% Coverage

## CHAIR PLASTIC LIDS

Reference 25 - 0.03% Coverage

## BRC DESIGNS

Reference 26 - 0.05% Coverage

## RECYCLE PLASTIC CAPS

Reference 27 - 0.08% Coverage

## THREAD MADE FROM PLASTIC BOTTLES

<Internals\\D (05)\\Screenshots \_ ActivTrak> - § 6 references coded [1.69% Coverage]

Reference 1 - 0.42% Coverage

ARCHITECTURAL GEOMETERIC SCREENS

Reference 2 - 0.17% Coverage

GOOGLE SEARCH

Reference 3 - 0.18% Coverage

Microsoft Word

Reference 4 - 0.33% Coverage

ARCHITECTURAL TRAIN RAILS

Reference 5 - 0.46% Coverage

ARCHITECTURAL RECYCLING TRAIN RAILS

Reference 6 - 0.12% Coverage

PINTEREST

<Internals\\D (06)\\Screenshots \_ ActivTrak> - § 37 references coded [2.97% Coverage]

Reference 1 - 0.02% Coverage

SKETCHUP

Reference 2 - 0.03% Coverage

TRAIN RAILS

Reference 3 - 0.04% Coverage

GOOGLE SEARCH

Reference 4 - 0.13% Coverage

CAN YOU RECYCLE RAILROAD TRACKS FOR PROFIT?

Reference 5 - 0.04% Coverage

YAHOO ANSWERS

Reference 6 - 0.05% Coverage

GOOGLE TRANSALTE

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RECYCLED RAILWAY TRACK

Reference 9 - 0.04% Coverage

renovateforum

Reference 10 - 0.11% Coverage

RAILROAD SCRAP AND USED RAIL SERVICES

Reference 11 - 0.06% Coverage

RECYCLING CONSULTANTS

Reference 12 - 0.10% Coverage

WHAT HAPPENS TO OLD TRAIN TRACKS

Reference 13 - 0.04% Coverage

WONDEROPOLIS

Reference 14 - 0.06% Coverage

NAKED SCIENCE FORUM

Reference 15 - 0.23% Coverage

IS IT POSSIBLE TO USE OLD TRAIN RAILS AS A STRUCTURAL ELEMENT IN A BUILDING?

Reference 16 - 0.02% Coverage

TRACK

Reference 17 - 0.03% Coverage

WIKIPEDIA

Reference 18 - 0.09% Coverage

THINGS TO DO WITH PLAST LIDS

Reference 19 - 0.10% Coverage

CLEVER WAYS TO REUSE PLASTIC LIDS

Reference 20 - 0.11% Coverage

<http://www.onegoodthingbyjillee.com>

Reference 21 - 0.11% Coverage

## THINGS TO DO WITH BOTTLE PLASTIC LIDS

Reference 22 - 0.06% Coverage

## GREEN KIDS NOW BLOGS

Reference 23 - 0.09% Coverage

## FUN ACTIVITIES WITH BOTTLE TOPS

Reference 24 - 0.05% Coverage

## LEARNING 4 KIDS

Reference 25 - 0.06% Coverage

## USES FOR PLASTIC LIDS

Reference 26 - 0.03% Coverage

## THRIFTYFUN

Reference 27 - 0.19% Coverage

## ARTISTIC WAYS TO RECYCLE BOTTLE CAPS, RECYCLED CRAFTS FOR KIDS

Reference 28 - 0.10% Coverage

## WAYS TO REUSE PLASTIC BOTTLE CAPS

Reference 29 - 0.06% Coverage

## CARE2 HEALTHY LIVING

Reference 30 - 0.09% Coverage

## RE USE OF BOTTLE PLASTIC LIDS

Reference 31 - 0.16% Coverage

## IDEAS CREATIVAS PARA REUTILIZAR BOTELLAS DE PLÁSTICO

Reference 32 - 0.08% Coverage

<http://dominiomundial.com>

Reference 33 - 0.11% Coverage

## LAMPS MADE FROM PLASTIC BOTTLE LIDS

Reference 34 - 0.14% Coverage

## UPCYCLE US: LAMP MADE WITH PLASTIC BOTTLE CAPS

Reference 35 - 0.10% Coverage

<http://upcycleus.blogspot.com.au>

Reference 36 - 0.06% Coverage

## PROVOCATIVE PLASTICS

Reference 37 - 0.09% Coverage

<http://beachpackagingdesign.com>

<Internals\D (07)\Screenshots \_ ActivTrak> - § 6 references coded [0.83% Coverage]

Reference 1 - 0.18% Coverage

## REGENERATIVE DESIGN

Reference 2 - 0.09% Coverage

## WIKIPEDIA

Reference 3 - 0.15% Coverage

## LIGHT STRUCTURES

Reference 4 - 0.12% Coverage

## GOOGLE SEARCH

Reference 5 - 0.13% Coverage

## LTL ARCHITECTS

Reference 6 - 0.15% Coverage

## GOOGLE TRANSLATE

<Internals\D (08)\Screenshots \_ ActivTrak> - § 21 references coded [1.40% Coverage]

Reference 1 - 0.14% Coverage

## HOW TO RECYCLE BOTTLE LIDS INTO SLINGSHOTS

Reference 2 - 0.09% Coverage

<http://www.instructables.com>

Reference 3 - 0.11% Coverage

## WAYS TO REUSE PLASTIC BOTTLE CAPS

Reference 4 - 0.07% Coverage

## CARE2 HEALTHY LIVING

Reference 5 - 0.03% Coverage

EVERNOTE

Reference 6 - 0.07% Coverage

UPCYCLING PLASTIC LIDS

Reference 7 - 0.04% Coverage

GOOGLE SEARCH

Reference 8 - 0.07% Coverage

PLASTIC LIDS SCULPTURE

Reference 9 - 0.08% Coverage

PLASTIC LIDS ARCHITECTURE

Reference 10 - 0.03% Coverage

PINTEREST

Reference 11 - 0.06% Coverage

MELTED PLASTIC LIDS

Reference 12 - 0.03% Coverage

BROWSE ART

Reference 13 - 0.03% Coverage

DEVIANTART

Reference 14 - 0.08% Coverage

PLASTIC BOTTLE DIY IDEAS

Reference 15 - 0.06% Coverage

Adobe Photoshop CS6

Reference 16 - 0.08% Coverage

Rhinoceros 5.0 (64-bit)

Reference 17 - 0.07% Coverage

TRAIN RAILS RECYCLED

Reference 18 - 0.07% Coverage

TRAIN RAILS SCULPTURE

Reference 19 - 0.11% Coverage

HOW DO THEY BEND RAIL ROAD RAILS?

Reference 20 - 0.04% Coverage

YAHOO ANSWERS

Reference 21 - 0.05% Coverage

AUTODESK 3DS MAX

<Internals\D (09)\Screenshots \_ ActivTrak> - § 1 reference coded [0.48% Coverage]

Reference 1 - 0.48% Coverage

Microsoft Word

<Internals\D (09)\Screenshots \_ ActivTrak1> - § 2 references coded [0.41% Coverage]

Reference 1 - 0.18% Coverage

TRAIN RAIL

Reference 2 - 0.23% Coverage

GOOGLE SEARCH

<Internals\D (10)\Screenshots \_ ActivTrak> - § 8 references coded [1.15% Coverage]

References 1-2 - 0.17% Coverage

Microsoft Office Word

Reference 3 - 0.33% Coverage

HOW TO EMBED 3D OBJECTS IN RESIN ARTWORK

Reference 4 - 0.06% Coverage

YOUTUBE

Reference 5 - 0.16% Coverage

RAILROAD RAIL PIECES

Reference 6 - 0.11% Coverage

GOOGLE SEARCH

Reference 7 - 0.16% Coverage

GRAPHISOFT ARCHICAD

Reference 8 - 0.16% Coverage

RAILROAD RAIL PIECES

## **Name: Nodes\\Data details\\Computer activity\\Applications**

<Internals\\D (01)\\Screenshots \_ ActivTrak> - § 1 reference coded [0.03% Coverage]

Reference 1 - 0.03% Coverage

WORD

<Internals\\D (02)\\Screenshots \_ ActivTrak> - § 1 reference coded [0.08% Coverage]

Reference 1 - 0.08% Coverage

RHINOCEROS

<Internals\\D (03)\\Screenshots \_ ActivTrak> - § 1 reference coded [0.48% Coverage]

Reference 1 - 0.48% Coverage

Microsoft Word

<Internals\\D (04)\\Screenshots \_ ActivTrak> - § 3 references coded [0.10% Coverage]

Reference 1 - 0.05% Coverage

GRAPHISOFT ARCHICAD

Reference 2 - 0.03% Coverage

MICROSOFT WORD

Reference 3 - 0.02% Coverage

SKETCHUP

<Internals\\D (05)\\Screenshots \_ ActivTrak> - § 1 reference coded [0.18% Coverage]

Reference 1 - 0.18% Coverage

Microsoft Word

<Internals\\D (06)\\Screenshots \_ ActivTrak> - § 2 references coded [0.07% Coverage]

Reference 1 - 0.02% Coverage

SKETCHUP

Reference 2 - 0.04% Coverage

Microsoft Word

<Internals\D (08)\Screenshots \_ ActivTrak> - § 4 references coded [0.22% Coverage]

Reference 1 - 0.03% Coverage

EVERNOTE

Reference 2 - 0.06% Coverage

Adobe Photoshop CS6

Reference 3 - 0.08% Coverage

Rhinoceros 5.0 (64-bit)

Reference 4 - 0.05% Coverage

AUTODESK 3DS MAX

<Internals\D (09)\Screenshots \_ ActivTrak> - § 1 reference coded [0.48% Coverage]

Reference 1 - 0.48% Coverage

Microsoft Word

<Internals\D (10)\Screenshots \_ ActivTrak> - § 2 references coded [0.33% Coverage]

Reference 1 - 0.17% Coverage

Microsoft Office Word

Reference 2 - 0.16% Coverage

GRAPHISOFT ARCHICAD

## **Name: Nodes\Data details\Computer activity\Key-words search**

<Internals\D (01)\Screenshots \_ ActivTrak> - § 10 references coded [1.58% Coverage]

Reference 1 - 0.14% Coverage

PLASTIC LEADS WALL

Reference 2 - 0.16% Coverage

UPCYCLE WOODEN SLATS

Reference 3 - 0.22% Coverage

HOW TO GROW MOSS ON PLASTIC

Reference 4 - 0.21% Coverage

DOES MOSS GROW ON PLASTIC?

Reference 5 - 0.15% Coverage

UPCYCLING RAIL TIES

Reference 6 - 0.16% Coverage

UPCYCLING RAIL LINES

Reference 7 - 0.12% Coverage

UPCYCLING RAILS

Reference 8 - 0.17% Coverage

UPCYCLING TRAIN RAILS

Reference 9 - 0.14% Coverage

RAIL TRAILS REUSED

Reference 10 - 0.10% Coverage

RECYCLED RAIL

<Internals\D (02)\Screenshots \_ ActivTrak> - § 2 references coded [0.38% Coverage]

Reference 1 - 0.21% Coverage

DESIGNS USING PLASTIC CAPS

Reference 2 - 0.17% Coverage

RECYCLED RAILS DESIGN

<Internals\D (03)\Screenshots \_ ActivTrak1> - § 2 references coded [0.41% Coverage]

Reference 1 - 0.18% Coverage

TRAIN RAIL

Reference 2 - 0.23% Coverage

CUTTIN A RAIL

<Internals\D (04)\Screenshots \_ ActivTrak> - § 15 references coded [0.95% Coverage]

Reference 1 - 0.07% Coverage

RECYCLE LIDS PLASTIC BOTTLES

Reference 2 - 0.06% Coverage

## TOYS FROM RECYCLED LIDS

Reference 3 - 0.06% Coverage

## PROJECTS WITH PLASTIC LIDS

Reference 4 - 0.06% Coverage

## EASY WAYS TO GLUE PLASTIC

Reference 5 - 0.06% Coverage

## APARELHO SOLDAR PLÁSTICO

Reference 6 - 0.08% Coverage

## HOW TO RECYCLE PLASTIC CAPS & LIDS

Reference 7 - 0.08% Coverage

## HOW TO CONNECT TWO PLASTIC LIDS

Reference 8 - 0.05% Coverage

## LANDSCAPE FURNITURE

Reference 9 - 0.06% Coverage

## STEEL LANDSCAPE FURNITURE

Reference 10 - 0.05% Coverage

## FURNITURE WITH RAILS

Reference 11 - 0.04% Coverage

## RAIL YARD STUDIOS

Reference 12 - 0.10% Coverage

## 25 WAYS WITH BOTTLE TOPS & PLASTIC CAPS

Reference 13 - 0.04% Coverage

## CHAIR PLASTIC LIDS

Reference 14 - 0.05% Coverage

## RECYCLE PLASTIC CAPS

Reference 15 - 0.08% Coverage

## THREAD MADE FROM PLASTIC BOTTLES

<Internals\\D (05)\\Screenshots \_ ActivTrak> - § 3 references coded [1.21% Coverage]

Reference 1 - 0.42% Coverage

ARCHITECTURAL GEOMETERIC SCREENS

Reference 2 - 0.33% Coverage

ARCHITECTURAL TRAIN RAILS

Reference 3 - 0.46% Coverage

ARCHITECTURAL RECYCLING TRAIN RAILS

<Internals\\D (06)\\Screenshots \_ ActivTrak> - § 19 references coded [1.98% Coverage]

Reference 1 - 0.03% Coverage

TRAIN RAILS

Reference 2 - 0.13% Coverage

CAN YOU RECYCLE RAILROAD TRACKS FOR PROFIT?

Reference 3 - 0.07% Coverage

RECYCLED RAILWAY TRACK

Reference 4 - 0.11% Coverage

RAILROAD SCRAP AND USED RAIL SERVICES

Reference 5 - 0.10% Coverage

WHAT HAPPENS TO OLD TRAIN TRACKS

Reference 6 - 0.23% Coverage

IS IT POSSIBLE TO USE OLD TRAIN RAILS AS A STRUCTURAL ELEMENT IN A BUILDING?

Reference 7 - 0.02% Coverage

TRACK

Reference 8 - 0.09% Coverage

THINGS TO DO WITH PLAST LIDS

Reference 9 - 0.10% Coverage

CLEVER WAYS TO REUSE PLASTIC LIDS

Reference 10 - 0.11% Coverage

## THINGS TO DO WITH BOTTLE PLASTIC LIDS

Reference 11 - 0.09% Coverage

## FUN ACTIVITIES WITH BOTTLE TOPS

Reference 12 - 0.06% Coverage

## USES FOR PLASTIC LIDS

Reference 13 - 0.19% Coverage

## ARTISTIC WAYS TO RECYCLE BOTTLE CAPS, RECYCLED CRAFTS FOR KIDS

Reference 14 - 0.10% Coverage

## WAYS TO REUSE PLASTIC BOTTLE CAPS

Reference 15 - 0.09% Coverage

## RE USE OF BOTTLE PLASTIC LIDS

Reference 16 - 0.16% Coverage

## IDEAS CREATIVAS PARA REUTILIZAR BOTELLAS DE PLÁSTICO

Reference 17 - 0.11% Coverage

## LAMPS MADE FROM PLASTIC BOTTLE LIDS

Reference 18 - 0.14% Coverage

## UPCYCLE US: LAMP MADE WITH PLASTIC BOTTLE CAPS

Reference 19 - 0.06% Coverage

## PROVOCATIVE PLASTICS

<Internals\D (07)\Screenshots \_ ActivTrak> - § 2 references coded [0.33% Coverage]

Reference 1 - 0.18% Coverage

## REGENERATIVE DESIGN

Reference 2 - 0.15% Coverage

## LIGHT STRUCTURES

<Internals\D (08)\Screenshots \_ ActivTrak> - § 11 references coded [0.88% Coverage]

Reference 1 - 0.14% Coverage

## HOW TO RECYCLE BOTTLE LIDS INTO SLINGSHOTS

Reference 2 - 0.11% Coverage

## WAYS TO REUSE PLASTIC BOTTLE CAPS

Reference 3 - 0.07% Coverage

## UPCYCLING PLASTIC LIDS

Reference 4 - 0.07% Coverage

## PLASTIC LIDS SCULPTURE

Reference 5 - 0.08% Coverage

## PLASTIC LIDS ARCHITECTURE

Reference 6 - 0.06% Coverage

## MELTED PLASTIC LIDS

Reference 7 - 0.03% Coverage

## BROWSE ART

Reference 8 - 0.08% Coverage

## PLASTIC BOTTLE DIY IDEAS

Reference 9 - 0.07% Coverage

## TRAIN RAILS RECYCLED

Reference 10 - 0.07% Coverage

## TRAIN RAILS SCULPTURE

Reference 11 - 0.11% Coverage

## HOW DO THEY BEND RAIL ROAD RAILS?

<Internals\D (09)\Screenshots \_ ActivTrak1> - § 1 reference coded [0.18% Coverage]

Reference 1 - 0.18% Coverage

## TRAIN RAIL

<Internals\D (10)\Screenshots \_ ActivTrak> - § 4 references coded [0.83% Coverage]

Reference 1 - 0.17% Coverage

## Microsoft Office Word

Reference 2 - 0.33% Coverage

## HOW TO EMBED 3D OBJECTS IN RESIN ARTWORK

Reference 3 - 0.16% Coverage

RAILROAD RAIL PIECES

Reference 4 - 0.16% Coverage

RAILROAD RAIL PIECES

## **Name: Nodes\\Data details\\Computer activity\\Websites**

<Internals\\D (01)\\Screenshots \_ ActivTrak> - § 2 references coded [0.28% Coverage]

Reference 1 - 0.10% Coverage

GOOGLE SEARCH

Reference 2 - 0.18% Coverage

THE PLANTED TANK FORUM

<Internals\\D (02)\\Screenshots \_ ActivTrak> - § 1 reference coded [0.10% Coverage]

Reference 1 - 0.10% Coverage

GOOGLE SEARCH

<Internals\\D (03)\\Screenshots \_ ActivTrak1> - § 1 reference coded [0.23% Coverage]

Reference 1 - 0.23% Coverage

GOOGLE SEARCH

<Internals\\D (04)\\Screenshots \_ ActivTrak> - § 9 references coded [0.36% Coverage]

Reference 1 - 0.04% Coverage

TRANSLATE GOOGLE

Reference 2 - 0.03% Coverage

GOOGLE SEARCH

Reference 3 - 0.11% Coverage

PINTEREST: DISCOVER AND SAVE CREATIVE IDEAS

Reference 4 - 0.04% Coverage

CONEXÃO LUSÓFONA

Reference 5 - 0.02% Coverage

WIKIHOW

Reference 6 - 0.02% Coverage

YOUTUBE

Reference 7 - 0.05% Coverage

SCIENCE EXPERIMENTS

Reference 8 - 0.03% Coverage

DOMESBLISSITY

Reference 9 - 0.03% Coverage

BRC DESIGNS

<Internals\D (05)\Screenshots \_ ActivTrak> - § 2 references coded [0.29% Coverage]

Reference 1 - 0.17% Coverage

GOOGLE SEARCH

Reference 2 - 0.12% Coverage

PINTEREST

<Internals\D (06)\Screenshots \_ ActivTrak> - § 16 references coded [0.92% Coverage]

Reference 1 - 0.04% Coverage

GOOGLE SEARCH

Reference 2 - 0.04% Coverage

YAHOO ANSWERS

Reference 3 - 0.05% Coverage

GOOGLE TRANSALTE

Reference 4 - 0.04% Coverage

renovateforum

Reference 5 - 0.06% Coverage

RECYCLING CONSULTANTS

Reference 6 - 0.04% Coverage

WONDEROPOLIS

Reference 7 - 0.06% Coverage

NAKED SCIENCE FORUM

Reference 8 - 0.03% Coverage

WIKIPEDIA

Reference 9 - 0.11% Coverage

<http://www.onegoodthingbyjillee.com>

Reference 10 - 0.06% Coverage

GREEN KIDS NOW BLOGS

Reference 11 - 0.05% Coverage

LEARNING 4 KIDS

Reference 12 - 0.03% Coverage

THRIFTYFUN

Reference 13 - 0.06% Coverage

CARE2 HEALTHY LIVING

Reference 14 - 0.08% Coverage

<http://dominiomundial.com>

Reference 15 - 0.10% Coverage

<http://upcycleus.blogspot.com.au>

Reference 16 - 0.09% Coverage

<http://beachpackagingdesign.com>

<Internals\D (07)\Screenshots \_ ActivTrak> - § 4 references coded [0.50% Coverage]

Reference 1 - 0.09% Coverage

WIKIPEDIA

Reference 2 - 0.12% Coverage

GOOGLE SEARCH

Reference 3 - 0.13% Coverage

LTL ARCHITECTS

Reference 4 - 0.15% Coverage

GOOGLE TRANSLATE

<Internals\D (08)\Screenshots \_ ActivTrak> - § 6 references coded [0.30% Coverage]

Reference 1 - 0.09% Coverage

<http://www.instructables.com>

Reference 2 - 0.07% Coverage

CARE2 HEALTHY LIVING

Reference 3 - 0.04% Coverage

GOOGLE SEARCH

Reference 4 - 0.03% Coverage

PINTEREST

Reference 5 - 0.03% Coverage

DEVIANTART

Reference 6 - 0.04% Coverage

YAHOO ANSWERS

<Internals\D (09)\Screenshots \_ ActivTrak1> - § 1 reference coded [0.23% Coverage]

Reference 1 - 0.23% Coverage

GOOGLE SEARCH

<Internals\D (10)\Screenshots \_ ActivTrak> - § 2 references coded [0.16% Coverage]

Reference 1 - 0.06% Coverage

YOUTUBE

Reference 2 - 0.11% Coverage

GOOGLE SEARCH

## **Name: Nodes\Data details\Material Information**

<Internals\D (01)\survey\_20160504 04-14-06> - § 5 references coded [5.09% Coverage]

Reference 1 - 0.37% Coverage

plastic lids (different sizes and colours)

Reference 2 - 0.31% Coverage

recycled wooden slats, fishing line

Reference 3 - 0.29% Coverage

lids connected using fishing line

Reference 4 - 0.62% Coverage

resistant to the changing weather and will withstand even strong winds

Reference 5 - 3.49% Coverage

The reasoning behind using upcycled materials: - It teaches people from a very young age about recycling, how to use creativity to incorporate existing objects (often seen as useless) into building or artistic project. - People at a young age are exposed to alternative ideas which may influence and broaden their own imagination and further lead to a development of their own recycling ideas

<Internals\D (02)\survey\_20160504 03-46-03 (1)> - § 2 references coded [1.23% Coverage]

Reference 1 - 0.67% Coverage

Connected using cable ties threaded through pre-drilled holes

Reference 2 - 0.56% Coverage

welded together on site using custom steel brackets

<Internals\D (03)\Survey Results Area> - § 4 references coded [11.41% Coverage]

Reference 1 - 5.29% Coverage

4 distinct size b. A variety of colours c. A variety of textures d. A Variety of shapes (Different radiuses and in turn different turning circles.) e. The lids operate as gears where one put side by side with the other can create a turning motion. The dents on the sides of the lids contribute to this attribute of the lids. 2. The light emitted from each of the lids gives provides with a funky colour that is part of the characteristics of the lid. Hence the colour of each emitted light is different. 3. The fact that each lid comes in a different shape also changes the way each colour is emitted. Hence the form of each emitted light is different. 4. Since the light emitted is opaque, it is not see through. 5. By lighting a torch behind each of the lids, they light up, illuminating the inside of the lid and emitting a small light on the outside.

Reference 2 - 0.69% Coverage

utilizes all the observed properties of the light based on assumptions made that were raised from the challenges

Reference 3 - 4.63% Coverage

material is hard to move around as is very heavy and requires heavy machinery to cut. As each meter weights about 60kg smaller segments such as 30cm pieces would weight around 20kg each piece allowing for extra weights. This means that if the rail was to be cut down to smaller pieces it would be a lot more manageable. As the rail is a heavy material and is used industrially quite often, it is often unforeseen the shape that it withholds. The area between the head and foot where the web sits is connected to its adjacent parts through a smooth curve. This smooth

curve can replicate the size of a bottle. Wine bottle sizes come in a variety of 70-90mm circumferences and as the web size of the rail is 90 mm this gives around 20 mm of movement

Reference 4 - 0.79% Coverage

genuine brutalist connection to the structural integrity of an architecture that includes similar materials in its construction

<Internals\\D (04)\\survey\_20160428 02-45-17> - § 9 references coded [8.67% Coverage]

Reference 1 - 1.52% Coverage

Variable heights All of them: screws, texture around Most of them have smooth top It is not worth to deconstruct/recycle the lids (I believe they should be applied in their original rounded form)

Reference 2 - 3.67% Coverage

The second step was to create an easy connection that worked to keep them together. One issue to consider is that the screws inside (that could be used to slot the connection) have variable heights. Those joints could be printed in plastic or made off holes, screws and bolts (this option would make the piece heavy, so maybe is not appropriate). The perfect joint would be made out of reclaimed stuff but more time is needed to develop a connection for jointing the lids

Reference 3 - 0.37% Coverage

good stability when under pressure on their top

Reference 4 - 0.29% Coverage

guided through a recent personal need

Reference 5 - 0.55% Coverage

being a plastic mat that could be used outside in a varanda or a garden

Reference 6 - 0.68% Coverage

I haven't checked if there is enough lids for my proposal or if I had to save some more

Reference 7 - 0.87% Coverage

Its elongated form and heaviness make us think they would be more appropriate if used with a structural function

Reference 8 - 0.28% Coverage

pallets or glass to be the table top

Reference 9 - 0.44% Coverage

steel plates to connect pieces together – external joint

<Internals\\D (05)\\Survey Results Area> - § 1 reference coded [1.18% Coverage]

Reference 1 - 1.18% Coverage

linked together by a web structure Slicing the rail

<Internals\D (06)\Survey attachment\_D6> - § 6 references coded [9.65% Coverage]

Reference 1 - 3.61% Coverage

look more appropriate as an interior design object / non-structural architectural element, such as a lamp, a seat, a wall panel, a child toy or something else

Reference 2 - 1.44% Coverage

challenge perhaps should be to collect that huge amount of lids

Reference 3 - 0.82% Coverage

really nice urban renovation project

Reference 4 - 0.68% Coverage

help of children and community

Reference 5 - 1.80% Coverage

metal structure to support and lids are kind of sewed with nylon or metal wires

Reference 6 - 1.30% Coverage

how it would work with the heat, or with the risk of fire

<Internals\D (07)\survey\_20160504 02-50-43> - § 3 references coded [1.70% Coverage]

Reference 1 - 0.29% Coverage

lids as bases and connectors

Reference 2 - 0.84% Coverage

trying the materials in a playful manner and discovering different uses for them

Reference 3 - 0.57% Coverage

different uses, in public spaces or landscape projects

<Internals\D (08)\survey\_20160428 05-14-42> - § 3 references coded [5.87% Coverage]

Reference 1 - 1.85% Coverage

Most lids use HDPE plastic which can be melted down into flat sections using a sandwich press. The thickness, colour and shape of the material can be experimented with using material tests

Reference 2 - 3.78% Coverage

In this immediate site one potential use for this material could be to clad the entire interior of the room - walls, floors, ceiling. This would completely alter the spatial qualities of the site. Then the site could be used as a gallery for other sculptures and artworks developed using the same material. One example might be sculptures similar to the outsider art of M. Ringo White

#### Reference 3 - 0.24% Coverage

Sections could be welded

<Internals\D (09)\Survey Results Area> - § 5 references coded [9.32% Coverage]

#### Reference 1 - 0.92% Coverage

plastic, hard, light in weight, circular cylindrical shapes, and bright colours. Has structural mass and could support itself

#### Reference 2 - 0.38% Coverage

combination with other materials to create an object

#### Reference 3 - 3.57% Coverage

metal, hard, specific shape, and dark colour could be rusty. Has structural mass and will support itself. Originally designed to support heavy rail carriages travelling at speed. Designed to be supported on ground, material composition might not be designed to be used as structural support, as beams supported at either ends only or could be. Not sure of its tensile capability, can it support load on point, vertically not horizontally? Heavy, Weight could it be used to advantage

#### Reference 4 - 4.02% Coverage

Existing structural members with similar weight. Universal beams ( I Beam): UNIVERSAL BEAM 410mm X 59.7kg/m 59.7 weight per m<sup>2</sup>, 1.49 external surface area per meter, 406 depth of section, 178 flange width, 12.8 flange width, 7.8 web thickness, 381 depth between flanges. UNIVERSAL COLUMN 200mm X 59.5kg/m 59.5 weight per m<sup>2</sup>, 1.22 external surface area per meter, 210 depth of section 205 flange width 14.2 flange width 9.3 web thickness 181 depth between flanges. 155 ct 59 column Tee or Beam Tee ( cut from a UC section ) has similar weight

#### Reference 5 - 0.42% Coverage

Material mass, over 60% Carbon, melt it down for material

<Internals\D (10)\survey\_20160423 02-55-55> - § 4 references coded [2.49% Coverage]

#### Reference 1 - 0.61% Coverage

embedding them in concrete and sealing over with clear resin

#### Reference 2 - 0.35% Coverage

wide variety of colours and shapes

#### Reference 3 - 0.49% Coverage

heavy and will not be subjected to much movement

Reference 4 - 1.04% Coverage

having them cast into concrete piers. The existing bolt holes can be used for any vertical connections

## **Name: Nodes\\Data details\\Material Information\\Concept development or precedents**

<Internals\\D (01)\\survey\_20160504 04-14-06> - § 1 reference coded [3.49% Coverage]

Reference 1 - 3.49% Coverage

The reasoning behind using upcycled materials: - It teaches people from a very young age about recycling, how to use creativity to incorporate existing objects (often seen as useless) into building or artistic project. - People at a young age are exposed to alternative ideas which may influence and broaden their own imagination and further lead to a development of their own recycling ideas

<Internals\\D (03)\\Survey Results Area> - § 2 references coded [1.48% Coverage]

Reference 1 - 0.69% Coverage

utilizes all the observed properties of the light based on assumptions made that were raised from the challenges

Reference 2 - 0.79% Coverage

genuine brutalist connection to the structural integrity of an architecture that includes similar materials in its construction

<Internals\\D (04)\\survey\_20160428 02-45-17> - § 1 reference coded [0.29% Coverage]

Reference 1 - 0.29% Coverage

guided through a recent personal need

<Internals\\D (06)\\Survey attachment\_D6> - § 2 references coded [1.51% Coverage]

Reference 1 - 0.82% Coverage

really nice urban renovation project

Reference 2 - 0.68% Coverage

help of children and community

<Internals\\D (07)\\survey\_20160504 02-50-43> - § 2 references coded [1.41% Coverage]

Reference 1 - 0.84% Coverage

trying the materials in a playful manner and discovering different uses for them

Reference 2 - 0.57% Coverage

different uses, in public spaces or landscape projects

<Internals\D (08)\survey\_20160428 05-14-42> - § 1 reference coded [3.78% Coverage]

Reference 1 - 3.78% Coverage

In this immediate site one potential use for this material could be to clad the entire interior of the room - walls, floors, ceiling. This would completely alter the spatial qualities of the site. Then the site could be used as a gallery for other sculptures and artworks developed using the same material. One example might be sculptures similar to the outsider art of M. Ringo White

## **Name: Nodes\Data details\Material Information\Connections**

<Internals\D (01)\survey\_20160504 04-14-06> - § 1 reference coded [0.29% Coverage]

Reference 1 - 0.29% Coverage

lids connected using fishing line

<Internals\D (02)\survey\_20160504 03-46-03 (1)> - § 2 references coded [1.23% Coverage]

Reference 1 - 0.67% Coverage

Connected using cable ties threaded through pre-drilled holes

Reference 2 - 0.56% Coverage

welded together on site using custom steel brackets

<Internals\D (04)\survey\_20160428 02-45-17> - § 2 references coded [4.11% Coverage]

Reference 1 - 3.67% Coverage

The second step was to create an easy connection that worked to keep them together. One issue to consider is that the screws inside (that could be used to slot the connection) have variable heights. Those joints could be printed in plastic or made off holes, screws and bolts (this option would make the piece heavy, so maybe is not appropriate). The perfect joint would be made out of reclaimed stuff but more time is needed to develop a connection for jointing the lids

Reference 2 - 0.44% Coverage

steel plates to connect pieces together – external joint

<Internals\D (05)\Survey Results Area> - § 1 reference coded [1.18% Coverage]

Reference 1 - 1.18% Coverage

linked together by a web structure Slicing the rail

<Internals\D (06)\Survey attachment\_D6> - § 1 reference coded [1.80% Coverage]

Reference 1 - 1.80% Coverage

metal structure to support and lids are kind of sewed with nylon or metal wires

<Internals\D (07)\survey\_20160504 02-50-43> - § 1 reference coded [0.29% Coverage]

Reference 1 - 0.29% Coverage

lids as bases and connectors

<Internals\D (08)\survey\_20160428 05-14-42> - § 1 reference coded [0.24% Coverage]

Reference 1 - 0.24% Coverage

Sections could be welded

<Internals\D (10)\survey\_20160423 02-55-55> - § 2 references coded [1.65% Coverage]

Reference 1 - 0.61% Coverage

embedding them in concrete and sealing over with clear resin

Reference 2 - 1.04% Coverage

having them cast into concrete piers. The existing bolt holes can be used for any vertical connections

## **Name: Nodes\Data details\Material Information\Material Addition**

<Internals\D (01)\survey\_20160504 04-14-06> - § 1 reference coded [0.31% Coverage]

Reference 1 - 0.31% Coverage

recycled wooden slats, fishing line

<Internals\D (04)\survey\_20160428 02-45-17> - § 1 reference coded [0.28% Coverage]

Reference 1 - 0.28% Coverage

pallets or glass to be the table top

<Internals\D (09)\Survey Results Area> - § 1 reference coded [0.38% Coverage]

Reference 1 - 0.38% Coverage

combination with other materials to create an object

## **Name: Nodes\\Data details\\Material Information\\Material availability**

<Internals\\D (04)\\survey\_20160428 02-45-17> - § 1 reference coded [0.68% Coverage]

Reference 1 - 0.68% Coverage

I haven't checked if there is enough lids for my proposal or if I had to save some more

<Internals\\D (06)\\Survey attachment\_D6> - § 2 references coded [3.24% Coverage]

Reference 1 - 1.44% Coverage

challenge perhaps should be to collect that huge amount of lids

Reference 2 - 1.80% Coverage

competition between schools, or some collection points around the train station

## **Name: Nodes\\Data details\\Material Information\\Material properties**

<Internals\\D (01)\\survey\_20160504 04-14-06> - § 2 references coded [1.00% Coverage]

Reference 1 - 0.37% Coverage

plastic lids (different sizes and colours)

Reference 2 - 0.62% Coverage

resistant to the changing weather and will withstand even strong winds

<Internals\\D (03)\\Survey Results Area> - § 2 references coded [9.93% Coverage]

Reference 1 - 5.29% Coverage

4 distinct size b. A variety of colours c. A variety of textures d. A Variety of shapes (Different radiuses and in turn different turning circles.) e. The lids operate as gears where one put side by side with the other can create a turning motion. The dents on the sides of the lids contribute to this attribute of the lids. 2. The light emitted from each of the lids gives provides with a funky colour that is part of the characteristics of the lid. Hence the colour of each emitted light is different. 3. The fact that each lid comes in a different shape also changes the way each colour is emitted. Hence the form of each emitted light is different. 4. Since the light emitted is opaque, it is not see through. 5. By lighting a torch behind each of the lids, they light up, illuminating the inside of the lid and emitting a small light on the outside.

Reference 2 - 4.63% Coverage

material is hard to move around as is very heavy and requires heavy machinery to cut. As each meter weights about 60kg smaller segments such as 30cm pieces would weight around 20kg each piece allowing for extra weights. This means that if the rail was to be cut down to smaller pieces it would be a lot more manageable. As the rail is a heavy material and is used industrially quite often, it is often unforeseen the shape that it withholds. The area between the head and foot where the web sits is connected to its adjacent parts through a smooth curve. This smooth curve can replicate the size of a bottle. Wine bottle sizes come in a variety of 70-90mm circumferences and as the web size of the rail is 90 mm this gives around 20 mm of movement

<Internals\D (04)\survey\_20160428 02-45-17> - § 4 references coded [3.31% Coverage]

Reference 1 - 1.52% Coverage

Variable heights All of them: screws, texture around Most of them have smooth top It is not worth to deconstruct/recycle the lids (I believe they should be applied in their original rounded form)

Reference 2 - 0.37% Coverage

good stability when under pressure on their top

Reference 3 - 0.55% Coverage

being a plastic mat that could be used outside in a varanda or a garden

Reference 4 - 0.87% Coverage

Its elongated form and heaviness make us think they would be more appropriate if used with a structural function

<Internals\D (06)\Survey attachment\_D6> - § 2 references coded [4.91% Coverage]

Reference 1 - 3.61% Coverage

look more appropriate as an interior design object / non-structural architectural element, such as a lamp, a seat, a wall panel, a child toy or something else

Reference 2 - 1.30% Coverage

how it would work with the heat, or with the risk of fire

<Internals\D (08)\survey\_20160428 05-14-42> - § 1 reference coded [1.85% Coverage]

Reference 1 - 1.85% Coverage

Most lids use HDPE plastic which can be melted down into flat sections using a sandwich press. The thickness, colour and shape of the material can be experimented with using material tests

<Internals\D (09)\Survey Results Area> - § 4 references coded [8.94% Coverage]

Reference 1 - 0.92% Coverage

plastic, hard, light in weight, circular cylindrical shapes, and bright colours. Has structural mass and could support itself

Reference 2 - 3.57% Coverage

metal, hard, specific shape, and dark colour could be rusty. Has structural mass and will support itself. Originally designed to support heavy rail carriages travelling at speed. Designed to be supported on ground, material composition might not be designed to be used as structural support, as beams supported at either ends only or could be. Not sure of its tensile capability, can it support load on point , vertically not horizontally? Heavy, Weight could it be used to advantage

Reference 3 - 4.02% Coverage

Existing structural members with similar weight. Universal beams ( I Beam): UNIVERSAL BEAM 410mm X 59.7kg/m 59.7 weight per m2, 1.49 external surface area per meter, 406 depth of section, 178 flange width, 12.8 flange width, 7.8 web thickness, 381 depth between flanges. UNIVERSAL COLUMN 200mm X 59.5kg/m 59.5 7 weight per m2, 1.22 external surface area per meter, 210 depth of section 205 flange width 14.2 flange width 9.3 web thickness 181 depth between flanges. 155 ct 59 column Tee or Beam Tee ( cut from a UC section ) has similar weight

Reference 4 - 0.42% Coverage

Material mass, over 60% Carbon, melt it down for material

<Internals\D (10)\survey\_20160423 02-55-55> - § 2 references coded [0.84% Coverage]

Reference 1 - 0.35% Coverage

wide variety of colours and shapes

Reference 2 - 0.49% Coverage

heavy and will not be subjected to much movement

## **Name: Nodes\Data details\Proposal A (LIDS)**

<Internals\D (01)\survey\_20160504 04-14-06> - § 1 reference coded [0.33% Coverage]

Reference 1 - 0.33% Coverage

set of division walls at a playground

<Internals\D (02)\survey\_20160504 03-46-03 (1)> - § 1 reference coded [0.14% Coverage]

Reference 1 - 0.14% Coverage

light fixture

<Internals\D (03)\Survey Results Area> - § 1 reference coded [0.15% Coverage]

Reference 1 - 0.15% Coverage

dynamic lighting fixture

<Internals\D (04)\survey\_20160428 02-45-17> - § 2 references coded [0.58% Coverage]

Reference 1 - 0.49% Coverage

interior pieces and even some panels for architecture composing

Reference 2 - 0.09% Coverage

colorful mat

<Internals\D (05)\Survey Results Area> - § 1 reference coded [1.39% Coverage]

Reference 1 - 1.39% Coverage

screen with different apertures, governed by the connections

<Internals\D (06)\Survey attachment\_D6> - § 3 references coded [0.84% Coverage]

Reference 1 - 0.23% Coverage

wall panel

Reference 2 - 0.14% Coverage

tunnel

Reference 3 - 0.48% Coverage

ceiling or table lamp

<Internals\D (07)\survey\_20160504 02-50-43> - § 1 reference coded [0.43% Coverage]

Reference 1 - 0.43% Coverage

shading structure to protect from the sun

<Internals\D (08)\survey\_20160428 05-14-42> - § 1 reference coded [0.36% Coverage]

Reference 1 - 0.36% Coverage

tiles and used as a cladding material

<Internals\D (09)\Survey Results Area> - § 5 references coded [1.41% Coverage]

Reference 1 - 0.57% Coverage

bubble diagram for space location and relationship between functions and site

Reference 2 - 0.29% Coverage

door stops, table legs base, door knobs

Reference 3 - 0.30% Coverage

lampshade, decorative pins, rings Jewelry

Reference 4 - 0.06% Coverage

cladding

Reference 5 - 0.19% Coverage

Light fitting, fruit bowl.

<Internals\D (10)\survey\_20160423 02-55-55> - § 2 references coded [1.24% Coverage]

Reference 1 - 0.84% Coverage

wayfinding assistance in either educational facilities or public health facilities

Reference 2 - 0.41% Coverage

use the patterns to form mosaic pictures

## **Name: Nodes\\Data details\\Proposal A\\Multiple solutions for lids**

<Internals\D (04)\survey\_20160428 02-45-17> - § 1 reference coded [0.49% Coverage]

Reference 1 - 0.49% Coverage

interior pieces and even some panels for architecture composing

<Internals\D (06)\Survey attachment\_D6> - § 3 references coded [0.84% Coverage]

Reference 1 - 0.23% Coverage

wall panel

Reference 2 - 0.14% Coverage

tunnel

Reference 3 - 0.48% Coverage

ceiling or table lamp

<Internals\D (09)\Survey Results Area> - § 5 references coded [1.41% Coverage]

Reference 1 - 0.57% Coverage

bubble diagram for space location and relationship between functions and site

Reference 2 - 0.29% Coverage

door stops, table legs base, door knobs

Reference 3 - 0.30% Coverage

lampshade, decorative pins, rings Jewelry

Reference 4 - 0.06% Coverage

cladding

Reference 5 - 0.19% Coverage

Light fitting, fruit bowl.

<Internals\D (10)\survey\_20160423 02-55-55> - § 1 reference coded [0.41% Coverage]

Reference 1 - 0.41% Coverage

use the patterns to form mosaic pictures

## **Name: Nodes\Data details\Proposal A\Single solution for lids**

<Internals\D (01)\survey\_20160504 04-14-06> - § 1 reference coded [0.33% Coverage]

Reference 1 - 0.33% Coverage

set of division walls at a playground

<Internals\D (02)\survey\_20160504 03-46-03 (1)> - § 1 reference coded [0.14% Coverage]

Reference 1 - 0.14% Coverage

light fixture

<Internals\D (03)\Survey Results Area> - § 1 reference coded [0.15% Coverage]

Reference 1 - 0.15% Coverage

dynamic lighting fixture

<Internals\D (04)\survey\_20160428 02-45-17> - § 1 reference coded [0.09% Coverage]

Reference 1 - 0.09% Coverage

colorful mat

<Internals\D (05)\Survey Results Area> - § 1 reference coded [1.39% Coverage]

Reference 1 - 1.39% Coverage

screen with different apertures, governed by the connections

<Internals\D (07)\survey\_20160504 02-50-43> - § 1 reference coded [0.43% Coverage]

Reference 1 - 0.43% Coverage

shading structure to protect from the sun

<Internals\D (08)\survey\_20160428 05-14-42> - § 1 reference coded [0.36% Coverage]

Reference 1 - 0.36% Coverage

tiles and used as a cladding material

<Internals\D (10)\survey\_20160423 02-55-55> - § 1 reference coded [0.84% Coverage]

Reference 1 - 0.84% Coverage

wayfinding assistance in either educational facilities or public health facilities

## **Name: Nodes\Data details\Proposal B (RAILS)**

<Internals\D (01)\survey\_20160504 04-14-06> - § 1 reference coded [0.15% Coverage]

Reference 1 - 0.15% Coverage

pedestrian bridge

<Internals\D (02)\survey\_20160504 03-46-03 (1)> - § 1 reference coded [0.24% Coverage]

Reference 1 - 0.24% Coverage

architectural pavilion

<Internals\D (03)\Survey Results Area> - § 1 reference coded [0.07% Coverage]

Reference 1 - 0.07% Coverage

wine holder

<Internals\D (04)\survey\_20160428 02-45-17> - § 3 references coded [0.96% Coverage]

Reference 1 - 0.37% Coverage

structural pieces for spaces, especially pillars

Reference 2 - 0.36% Coverage

landscape furniture or even interior furniture

Reference 3 - 0.23% Coverage

set of benches and table legs

<Internals\D (05)\Survey Results Area> - § 1 reference coded [0.58% Coverage]

Reference 1 - 0.58% Coverage

Sliding door rail Columns

<Internals\D (07)\survey\_20160504 02-50-43> - § 1 reference coded [0.08% Coverage]

Reference 1 - 0.08% Coverage

porticos

<Internals\D (08)\survey\_20160428 05-14-42> - § 1 reference coded [0.44% Coverage]

Reference 1 - 0.44% Coverage

stack 2000 sections of rail within a 50m cube

<Internals\D (09)\Survey Results Area> - § 2 references coded [2.87% Coverage]

Reference 1 - 1.46% Coverage

structural support replacement to Universal Column or beam. As it is : Structural retaining wall piles. As it is : floor joist additional advantage house / superstructure could move open and close.

Reference 2 - 1.41% Coverage

landscape sculpture, garden seat element, as in Tanner Springs Park, Portland, OR. Cut into small pieces can be used as hangers, wine racks, door handles, weights. free standing stair support

<Internals\D (10)\survey\_20160423 02-55-55> - § 1 reference coded [0.38% Coverage]

Reference 1 - 0.38% Coverage

outdoor public furniture installation

## **Name: Nodes\Data details\Proposal B\ Multiple solutions for rails**

<Internals\D (04)\survey\_20160428 02-45-17> - § 2 references coded [0.73% Coverage]

Reference 1 - 0.37% Coverage

structural pieces for spaces, especially pillars

Reference 2 - 0.36% Coverage

landscape furniture or even interior furniture

<Internals\D (09)\Survey Results Area> - § 2 references coded [2.87% Coverage]

Reference 1 - 1.46% Coverage

structural support replacement to Universal Column or beam. As it is: Structural retaining wall piles. As it is: floor joist additional advantage house / superstructure could move open and close.

Reference 2 - 1.41% Coverage

landscape sculpture, garden seat element, as in Tanner Springs Park, Portland, OR. Cut into small pieces can be used as hangers, wine racks, door handles, weights. free standing stair support

## **Name: Nodes\\Data details\\Proposal B\\Single solution for rails**

<Internals\\D (01)\\survey\_20160504 04-14-06> - § 1 reference coded [0.15% Coverage]

Reference 1 - 0.15% Coverage

pedestrian bridge

<Internals\\D (02)\\survey\_20160504 03-46-03 (1)> - § 1 reference coded [0.24% Coverage]

Reference 1 - 0.24% Coverage

architectural pavilion

<Internals\\D (03)\\Survey Results Area> - § 1 reference coded [0.07% Coverage]

Reference 1 - 0.07% Coverage

wine holder

<Internals\\D (04)\\survey\_20160428 02-45-17> - § 1 reference coded [0.23% Coverage]

Reference 1 - 0.23% Coverage

set of benches and table legs

<Internals\\D (05)\\Survey Results Area> - § 1 reference coded [0.58% Coverage]

Reference 1 - 0.58% Coverage

Sliding door rail Columns

<Internals\\D (07)\\survey\_20160504 02-50-43> - § 1 reference coded [0.08% Coverage]

Reference 1 - 0.08% Coverage

porticos

<Internals\\D (08)\\survey\_20160428 05-14-42> - § 1 reference coded [0.44% Coverage]

Reference 1 - 0.44% Coverage

stack 2000 sections of rail within a 50m cube

<Internals\\D (10)\\survey\_20160423 02-55-55> - § 1 reference coded [0.38% Coverage]

Reference 1 - 0.38% Coverage

outdoor public furniture installation

# Appendix B

## Intuitive Rematerial Interaction

Appendix B presents data processed within project 2, Intuitive Rematerial Interaction, relating design progression and outcomes from ROD performed by the novice designers. The material complies of the matrix guide for the generation of Tree Maps, master classification sheet showing all attributes and values assigned, the Tree Maps, and the Causality table, structured for the analysis.

The NVivo project file containing raw sources, node structure and classifications related to the project is available in a shared folder hosted by Dropbox service, accessible through the following link:

<https://www.dropbox.com/sh/vpy0r00y657x74o/AAC5t2XVY9oev7mian0x9S0da?dl=0>





### B3. Classification sheet, page 2

Connections intelligence	Concern on form and details of elements when designing	Cuts - Longitudinal wood slices
forced joinery	elements details considered	-
3d and form enhanced connections	elements details considered	-
3d and form enhanced connections	elements details considered	Wood pieces halved
forced joinery	elements details not considered	-
form enhances connections	elements details considered	-
forced joinery	elements details not considered	-
3d connections	elements details not considered	-
forced joinery	elements details not considered	Wood pieces halved
forced joinery	elements details not considered	-
forced joinery	elements details not considered	Wood pieces halved
forced joinery	elements details not considered	-
forced joinery	elements details not considered	-
forced joinery	elements details not considered	-
3d connections	elements details not considered	-
forced joinery	elements details not considered	Wood pieces halved
forced joinery	elements details not considered	Wood pieces halved
forced joinery	elements details not considered	Wood pieces halved
forced joinery	elements details not considered	-
forced joinery	elements details not considered	-
forced joinery	elements details not considered	-
3d connections	elements details considered	-
forced joinery	elements details not considered	-
forced joinery	elements details not considered	-
3d and form enhanced connections	elements details not considered	-
forced joinery	elements details not considered	-
form enhances connections	elements details not considered	-
3d connections	elements details not considered	-
forced joinery	elements details not considered	Wood pieces halved
3d connections	elements details not considered	-
3d connections	elements details not considered	-
3d and form enhanced connections	elements details not considered	-

**B4. Classification sheet, page 3**

Cuts - Transversal wood slices	Cuts - Whole wood pieces	Cuts of pieces - Metal pieces unified sized
-	-	-
-	-	-
-	-	-
-	Whole wood pieces	-
-	Whole wood pieces	Metal pieces unified sized
-	Whole wood pieces	Metal pieces unified sized
-	Whole wood pieces	Metal pieces unified sized
-	-	-
-	Whole wood pieces	-
-	-	Metal pieces unified sized
-	Whole wood pieces	Metal pieces unified sized
Slices of wood pieces	-	-
-	Whole wood pieces	-
-	Whole wood pieces	-
-	-	Metal pieces unified sized
-	-	-
-	-	-
Slices of wood pieces	-	-
-	Whole wood pieces	-
Slices of wood pieces	-	-
-	Whole wood pieces	-
Slices of wood pieces	-	-
Slices of wood pieces	-	-
-	Whole wood pieces	-
Slices of wood pieces	Whole wood pieces	Metal pieces unified sized
-	Whole wood pieces	Metal pieces unified sized
-	Whole wood pieces	-
-	-	Metal pieces unified sized
-	Whole wood pieces	Metal pieces unified sized
-	Whole wood pieces	Metal pieces unified sized
-	Whole wood pieces	-

**B5. Classification sheet, page 4**

Cuts of pieces -Metal pieces diverse sized	Documentation	Documentation reliability	Expectations
Metal pieces diverse sized	CAD Drawing	Partial and not reliable	Expectation reached
Metal pieces diverse sized	CAD Drawing	Complete but no reliable	Expectation exceeded
Metal pieces diverse sized	Hand Drawing CAD based	Complete and reliable	Expectation reached
-	Hand drawing	Partial and not reliable	Expectation not reached
-	Hand Drawing CAD based	Complete and reliable	Expectation exceeded
-	CAD Drawing	Partial and not reliable	Expectation not reached
-	Hand Drawing CAD based	Partial and not reliable	Expectation not reached
Metal pieces diverse sized	Hand drawing	Partial and not reliable	Expectation not reached
-	Hand drawing	Partial and reliable	Expectation reached
-	Hand Drawing CAD based	Partial and not reliable	Expectation reached
-	Hand Drawing CAD based	Partial and not reliable	Expectation not reached
-	Hand drawing	Partial and not reliable	Expectation not reached
Metal pieces diverse sized	Hand drawing	Partial and not reliable	Expectation not reached
-	Hand Drawing CAD based	Partial and not reliable	Expectation reached
-	Hand drawing	Partial and not reliable	Expectation reached
-	CAD Drawing	Partial and not reliable	Expectation not reached
-	CAD Drawing	Partial and not reliable	Expectation not reached
-	Hand Drawing CAD based	Partial and not reliable	Expectation not reached
Metal pieces diverse sized	Hand drawing	Partial and not reliable	Expectation not reached
Metal pieces diverse sized	Hand drawing	Partial and not reliable	Expectation not reached
-	Hand Drawing CAD based	Partial and not reliable	Expectation reached
-	CAD Drawing	Partial and not reliable	Expectation not reached
-	CAD Drawing	Partial and not reliable	Expectation not reached
Metal pieces diverse sized	Hand drawing	Partial and not reliable	Expectation not reached
-	Hand Drawing CAD based	Partial and not reliable	Expectation not reached
-	Hand drawing	Complete but no reliable	Expectation reached
-	Hand drawing	Partial and not reliable	Expectation not reached
-	Hand drawing	Partial and not reliable	Expectation not reached
-	Hand drawing	Partial and not reliable	Expectation not reached
-	Hand drawing	Partial and not reliable	Expectation not reached
-	Hand drawing	Partial and not reliable	Expectation not reached
-	CAD Drawing	Partial and not reliable	Expectation not reached

**B6. Classification sheet, page 5**

Formal intentions	Items adapted	Manufacture skills	Model feasibility
aesthetic and structural	Not Applicable	Not Applicable	Low feasibility
aesthetic and structural	material adapted	partially skilled	Medium feasibility
aesthetic and structural	Not Applicable	Not Applicable	highly feasible
intention aesthetic	Not Applicable	Not Applicable	Low feasibility
aesthetic and structural	material adapted	skilled	highly feasible
intention aesthetic	Not Applicable	Not Applicable	impracticable
intention aesthetic	Not Applicable	Not Applicable	highly feasible
intention structural	material, joints and shape adapted	not skilled	Low feasibility
aesthetic and structural	Not Applicable	Not Applicable	Medium feasibility
aesthetic and structural	Not Applicable	Not Applicable	highly feasible
aesthetic and structural	material, joints and shape adapted	partially skilled	Medium feasibility
intention aesthetic	Not Applicable	Not Applicable	impracticable
intention structural	Not Applicable	Not Applicable	Low feasibility
aesthetic and structural	Not Applicable	Not Applicable	Medium feasibility
intention aesthetic	Not Applicable	Not Applicable	Medium feasibility
intention aesthetic	Not Applicable	Not Applicable	impracticable
intention structural	Not Applicable	Not Applicable	impracticable
aesthetic and structural	Not Applicable	Not Applicable	impracticable
intention aesthetic	Not Applicable	Not Applicable	impracticable
aesthetic and structural	Not Applicable	Not Applicable	impracticable
aesthetic and structural	Not Applicable	Not Applicable	highly feasible
intention aesthetic	Not Applicable	Not Applicable	Low feasibility
intention aesthetic	Not Applicable	Not Applicable	impracticable
aesthetic and structural	Not Applicable	Not Applicable	Medium feasibility
aesthetic and structural	Not Applicable	Not Applicable	Medium feasibility
intention structural	Not Applicable	Not Applicable	Medium feasibility
aesthetic and structural	Not Applicable	Not Applicable	Medium feasibility
aesthetic and structural	Not Applicable	Not Applicable	Low feasibility
aesthetic and structural	Not Applicable	Not Applicable	Medium feasibility
aesthetic and structural	Not Applicable	Not Applicable	Medium feasibility
aesthetic and structural	Not Applicable	Not Applicable	Low feasibility

**B7. Classification sheet, page 6**

Model handleability	Model materials	Model stability	Modulation
handleable	cardboard and plywood	unstable under load	Clear repeated modules
not handleable	cardboard and pvc pipes	stable	Clear repeated modules
handleable	plywood or mdf	stable	Clear repeated modules
not handleable	Cardboard	unstable under load	organic form
handleable	Cardboard	stable	Clear twisted modules
not handleable	cardboard and plywood	unstable	Clear repeated modules
handleable	cardboard and wood rods	unstable under load	Clear repeated modules
handleable	cardboard and wood rods	unstable under load	Clear repeated modules
handleable	Cardboard	unstable under load	Clear repeated modules
handleable	cardboard and wood rods	stable	Clear repeated modules
handleable	cardboard and pvc pipes	stable	Clear repeated modules
not handleable	Cardboard	unstable	organic form
not handleable	Cardboard	unstable under load	Clear repeated modules
handleable	Cardboard	stable	Clear twisted modules
handleable	cardboard and wood rods	unstable under load	Clear repeated modules
not handleable	Cardboard	unstable	unclear modules
not handleable	Cardboard	stable	organic form
handleable	plywood or mdf	stable	organic form
not handleable	Cardboard	unstable	organic form
not handleable	plywood or mdf	unstable under load	organic form
handleable	Cardboard	stable	Clear twisted modules
not handleable	Cardboard	unstable	Clear repeated modules
not handleable	Cardboard	unstable	organic form
handleable	cardboard and pvc pipes	stable	Clear repeated modules
handleable	Cardboard	unstable under load	Clear repeated modules
handleable	Cardboard	stable	Clear repeated modules
handleable	Cardboard	stable	Clear repeated modules
handleable	plywood and wood rods	unstable under load	Clear repeated modules
handleable	cardboard and pvc pipes	unstable under load	Clear repeated modules
handleable	cardboard and pvc pipes	unstable under load	Clear twisted modules
not handleable	Cardboard	unstable under load	Clear repeated modules

**B8. Classification sheet, page 7**

Proposed Joints	Recognition scale of the pieces	Search of precedents
Joints clear on proposal	room recognition scale	No search of precedents
Joints clear on proposal	detail recognition scale	Search of precedents
Joints clear on proposal	room recognition scale	Search of precedents
Joints not clear on proposal	room recognition scale	Search of precedents
Joints clear on proposal	room recognition scale	Search of precedents
Joints not clear on proposal	detail recognition scale	No search of precedents
Joints clear on proposal	room recognition scale	No search of precedents
Joints not clear on proposal	room recognition scale	No search of precedents
Joints not clear on proposal	room recognition scale	Search of precedents
Joints clear on proposal	room recognition scale	No search of precedents
Joints not clear on proposal	room recognition scale	No search of precedents
Joints not clear on proposal	pieces not recognizable	No search of precedents
Joints not clear on proposal	room recognition scale	No search of precedents
Joints clear on proposal	room recognition scale	No search of precedents
Joints clear on proposal	detail recognition scale	No search of precedents
Joints not clear on proposal	pieces not recognizable	Search of precedents
Joints not clear on proposal	detail recognition scale	Search of precedents
Joints not clear on proposal	pieces not recognizable	Search of precedents
Joints not clear on proposal	pieces not recognizable	No search of precedents
Joints not clear on proposal	pieces not recognizable	No search of precedents
Joints clear on proposal	room recognition scale	No search of precedents
Joints not clear on proposal	detail recognition scale	No search of precedents
Joints not clear on proposal	pieces not recognizable	No search of precedents
Joints not clear on proposal	room recognition scale	No search of precedents
Joints clear on proposal	room recognition scale	No search of precedents
Joints clear on proposal	room recognition scale	No search of precedents
Joints clear on proposal	room recognition scale	No search of precedents
Joints not clear on proposal	room recognition scale	No search of precedents
Joints not clear on proposal	room recognition scale	No search of precedents
Joints not clear on proposal	room recognition scale	No search of precedents
Joints not clear on proposal	room recognition scale	No search of precedents

**B9. Classification sheet, page 8**

Tridimensional composition	Types - double metal barrel	Types - single metal barrel	Types - wood forestock
tridimensional composition	double metal barrel	single metal barrel	-
tridimensional composition	double metal barrel	single metal barrel	wood forestock
tridimensional composition	double metal barrel	single metal barrel	-
-	-	-	-
tridimensional composition	-	single metal barrel	-
-	double metal barrel	-	wood forestock
tridimensional composition	-	single metal barrel	-
-	double metal barrel	single metal barrel	-
tridimensional composition	-	-	-
tridimensional composition	double metal barrel	single metal barrel	-
tridimensional composition	-	single metal barrel	-
-	-	-	wood forestock
tridimensional composition	-	single metal barrel	-
tridimensional composition	-	-	-
-	-	single metal barrel	wood forestock
-	-	-	-
-	-	-	wood forestock
tridimensional composition	-	-	wood forestock
-	double metal barrel	single metal barrel	wood forestock
tridimensional composition	-	single metal barrel	wood forestock
tridimensional composition	-	single metal barrel	wood forestock
-	-	-	-
-	-	-	-
-	double metal barrel	single metal barrel	-
-	-	single metal barrel	-
-	-	single metal barrel	-
tridimensional composition	-	-	-
-	-	single metal barrel	-
tridimensional composition	-	single metal barrel	-
tridimensional composition	-	single metal barrel	-
tridimensional composition	-	-	-



**B11. Tree Maps of attribute value combinations**



**Figure 19. Tree Map 1 – Tridimensional composition and documentation methods**



**Figure 20. Tree Map 2 – Tridimensional composition and expectation**



Figure 21. Tree Map 3 – Tridimensional composition, feasibility and stability



Figure 22. Tree Map 4 -. concept development and expectation



Figure 23. Tree Map 5. connections intelligence

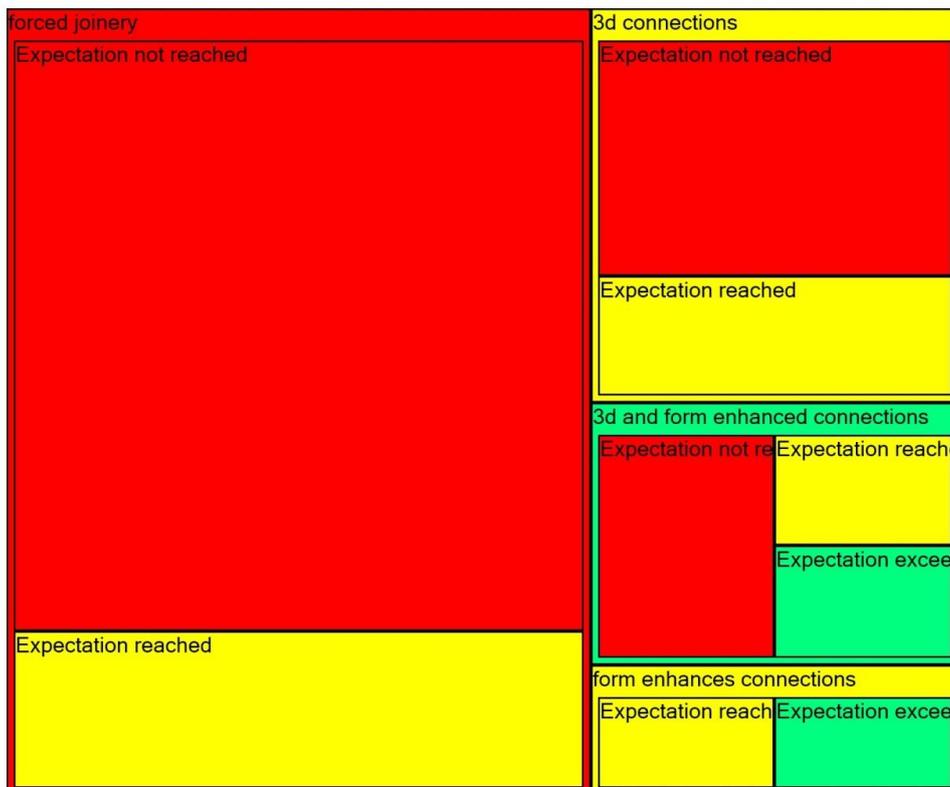


Figure 24. Tree Map 6. connections intelligence and expectations

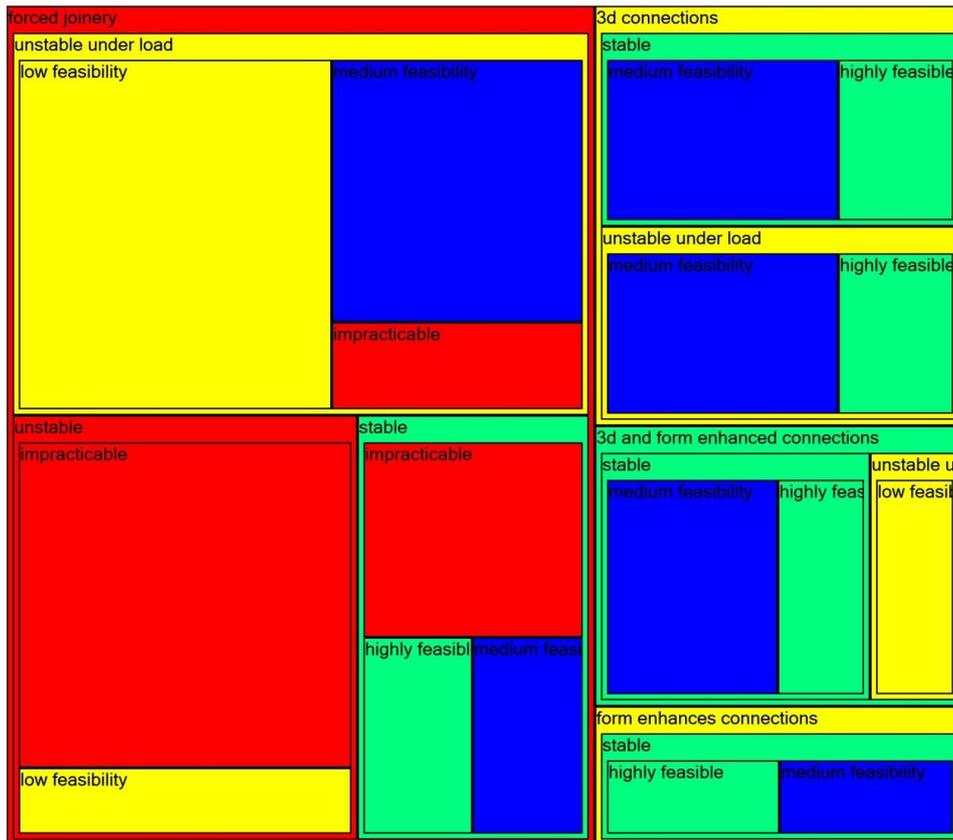


Figure 25. Tree Map 7. connections intelligence, stability and feasibility



Figure 26. Tree Map 8. documentation method, documentation quality and feasibility



Figure 27. Tree Map 9. documentation method, documentation quality and model stability



Figure 28. Tree Map 10. documentation method and expectation

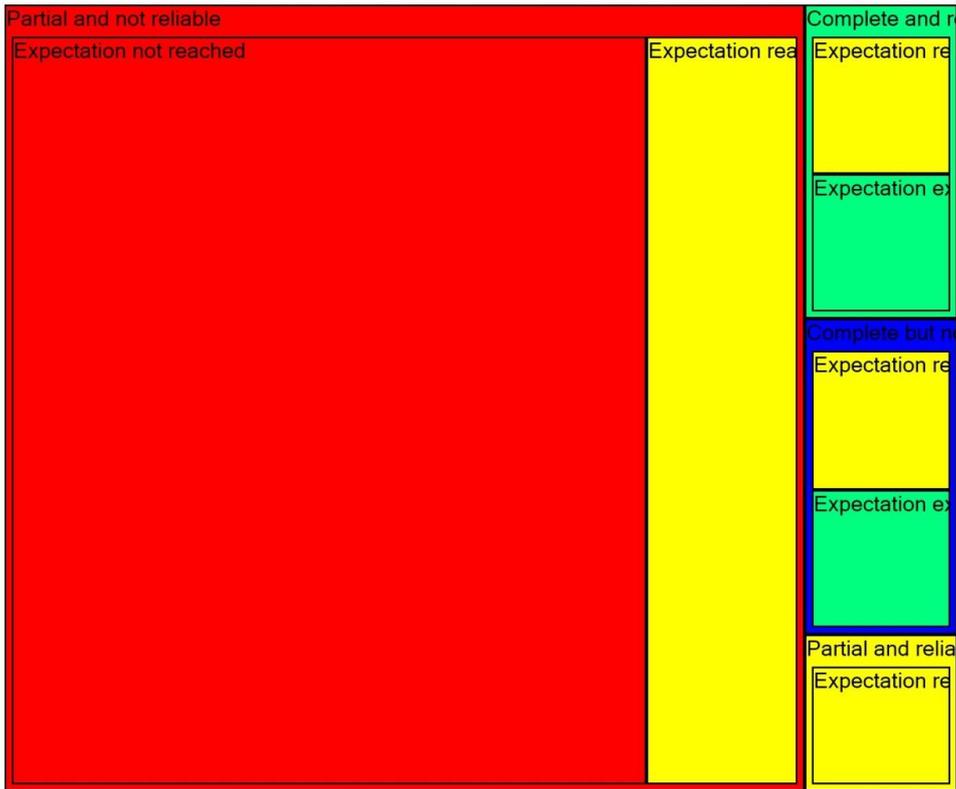


Figure 29. Tree Map 11. documentation quality and expectations



Figure 30. Tree Map 12. documentation quality and feasibility





Figure 33. Tree Map 15. Expectations and handleability

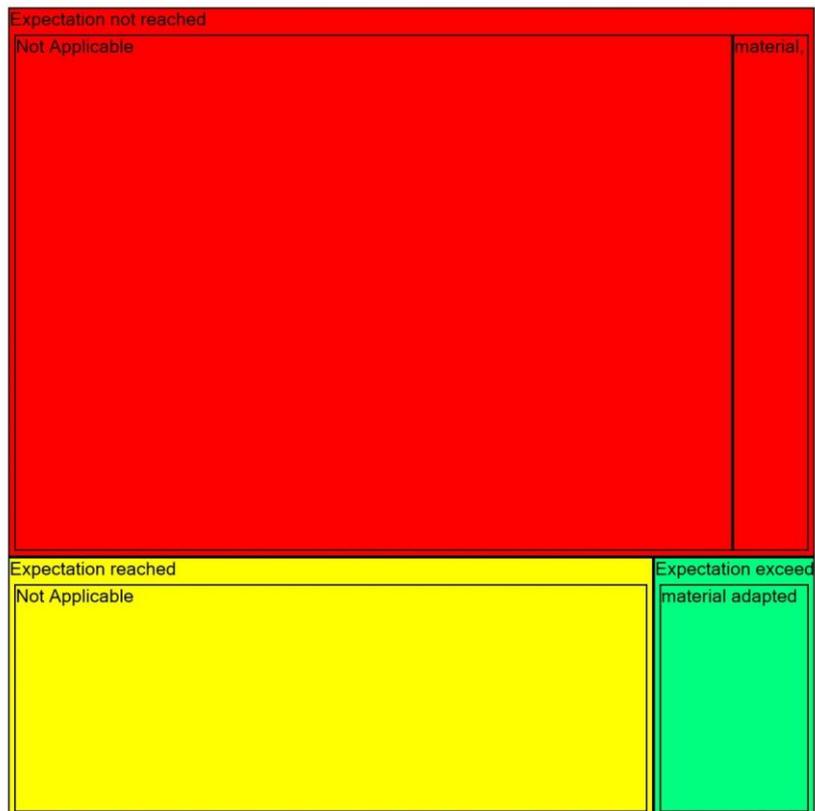


Figure 34. Tree Map 16. Expectations and items adapted

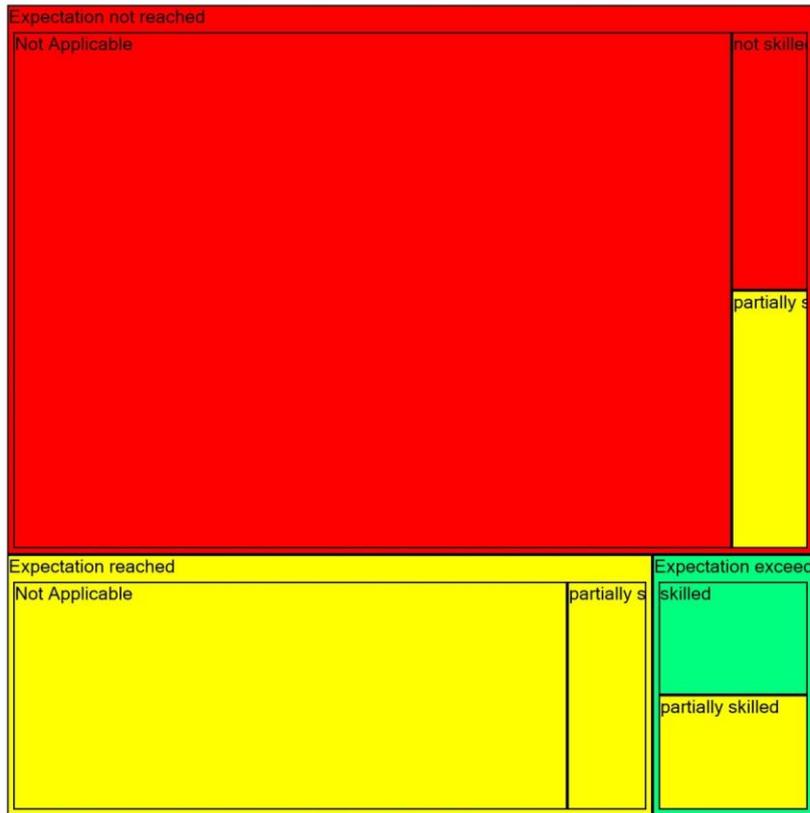


Figure 35. Tree Map 17. Expectations and manufacture skills

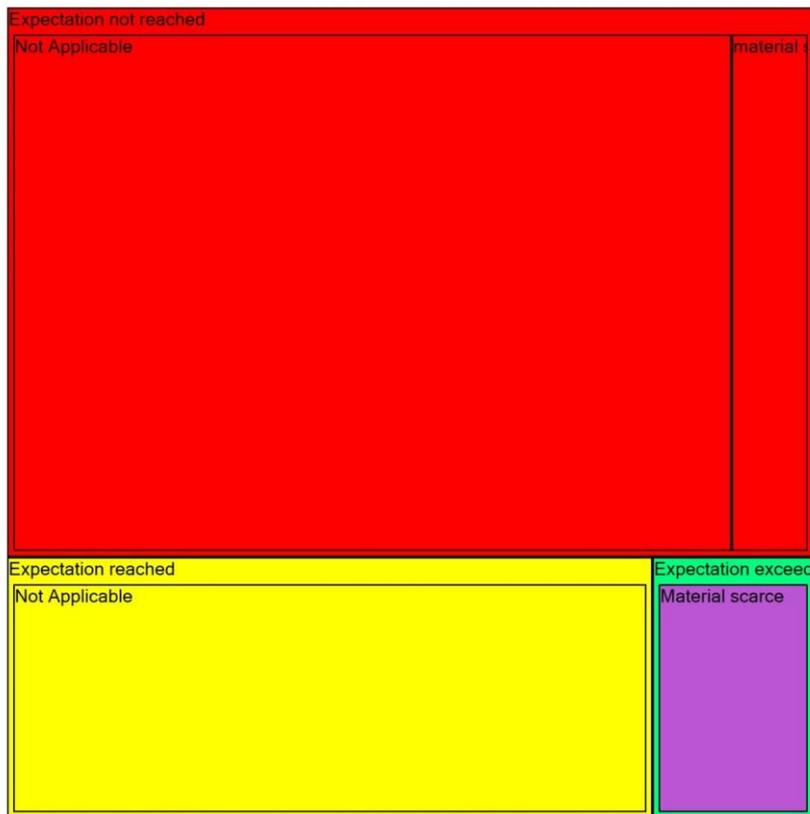


Figure 36. Tree Map 18. Expectations and reasons for redesign

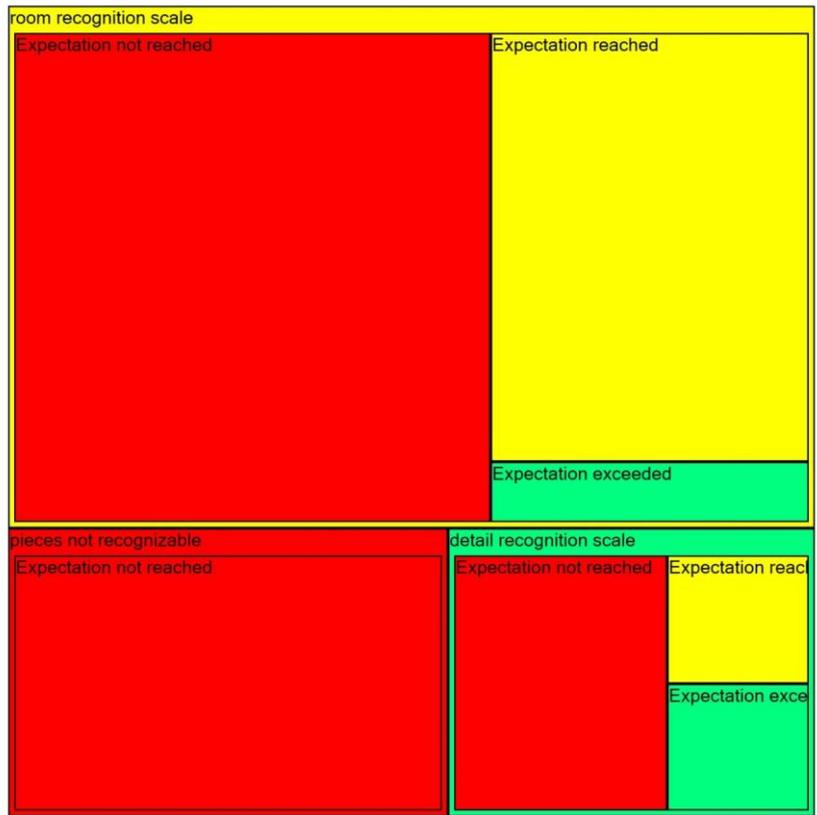


Figure 37. Tree Map 19. Expectations and recognition scale

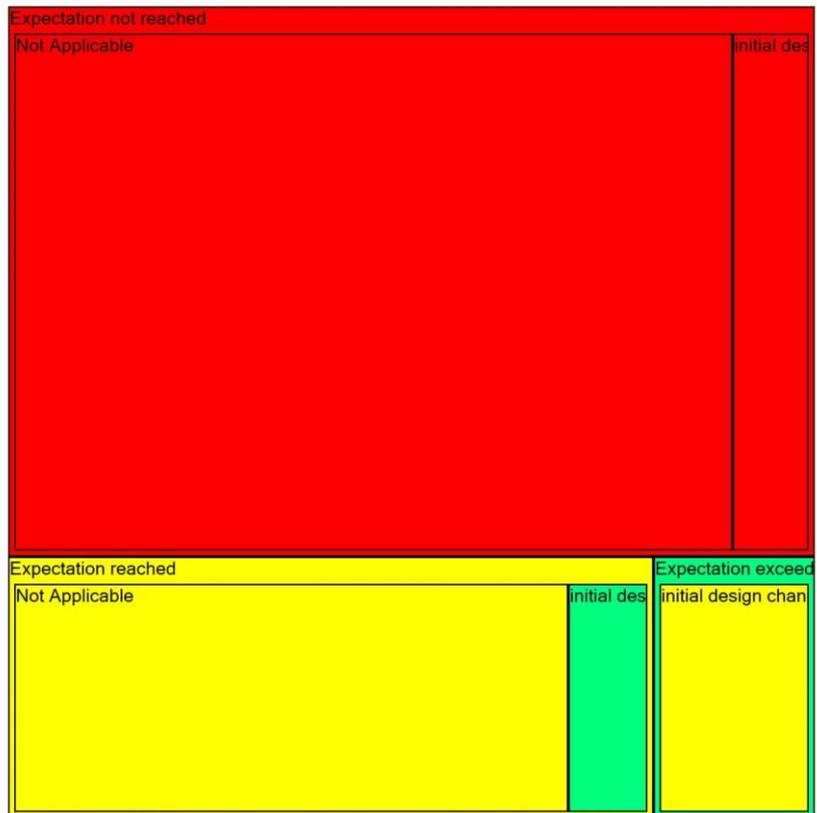


Figure 38. Tree Map 20. Expectations and redesign level

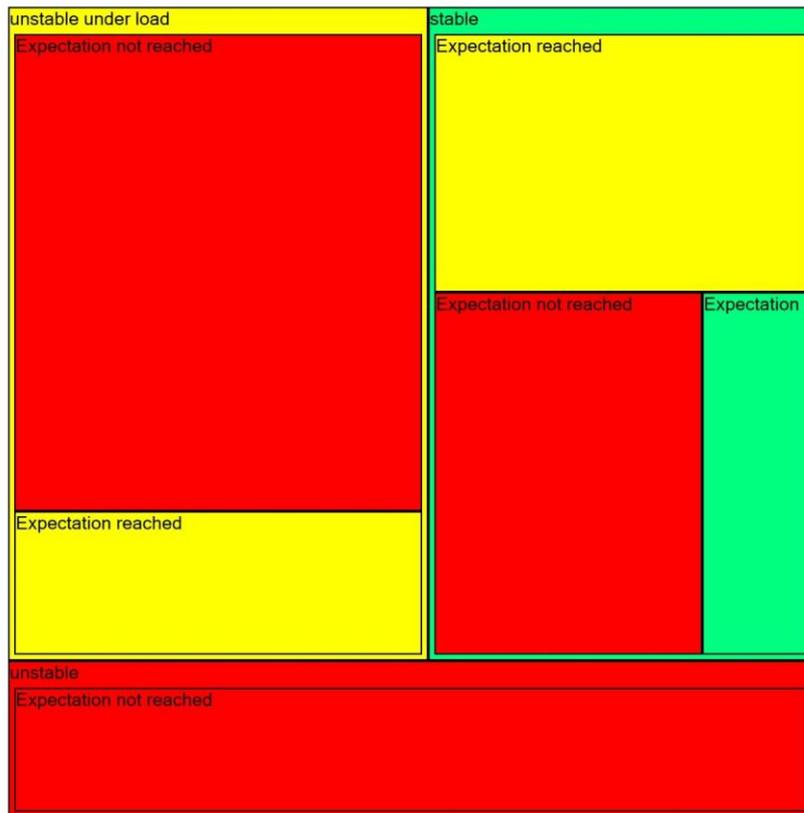


Figure 39. Tree Map 21. Expectations and stability



Figure 40. Tree Map 22. Feasibility and documentation methods

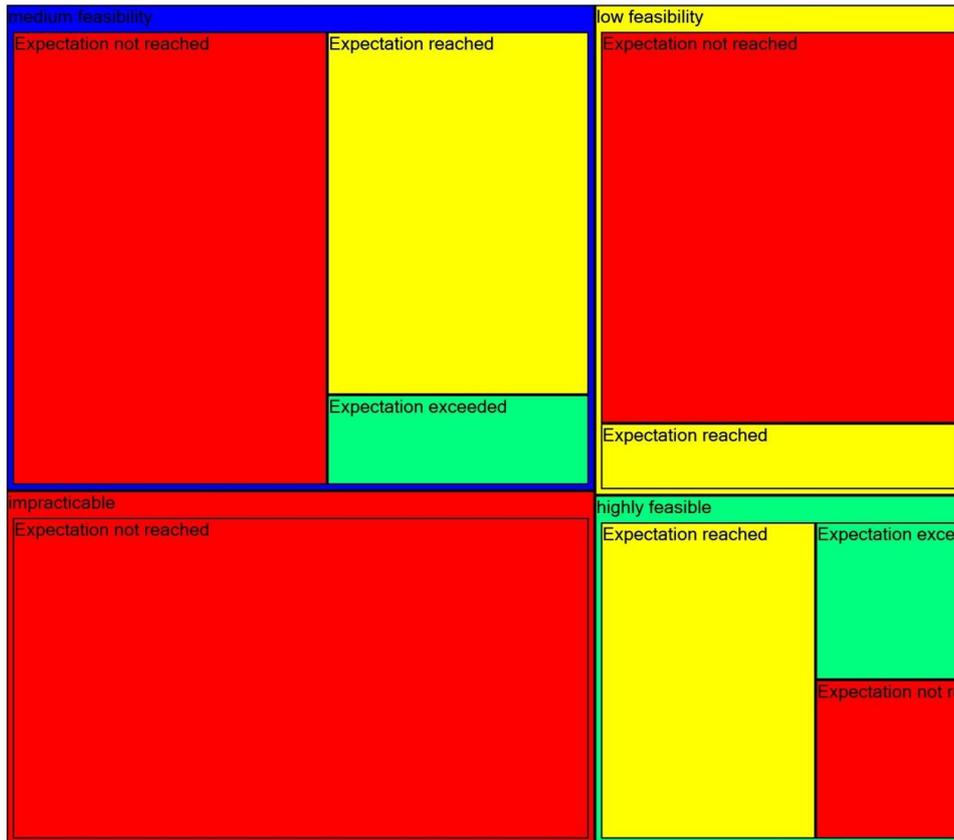


Figure 41. Tree Map 23. Feasibility and expectations

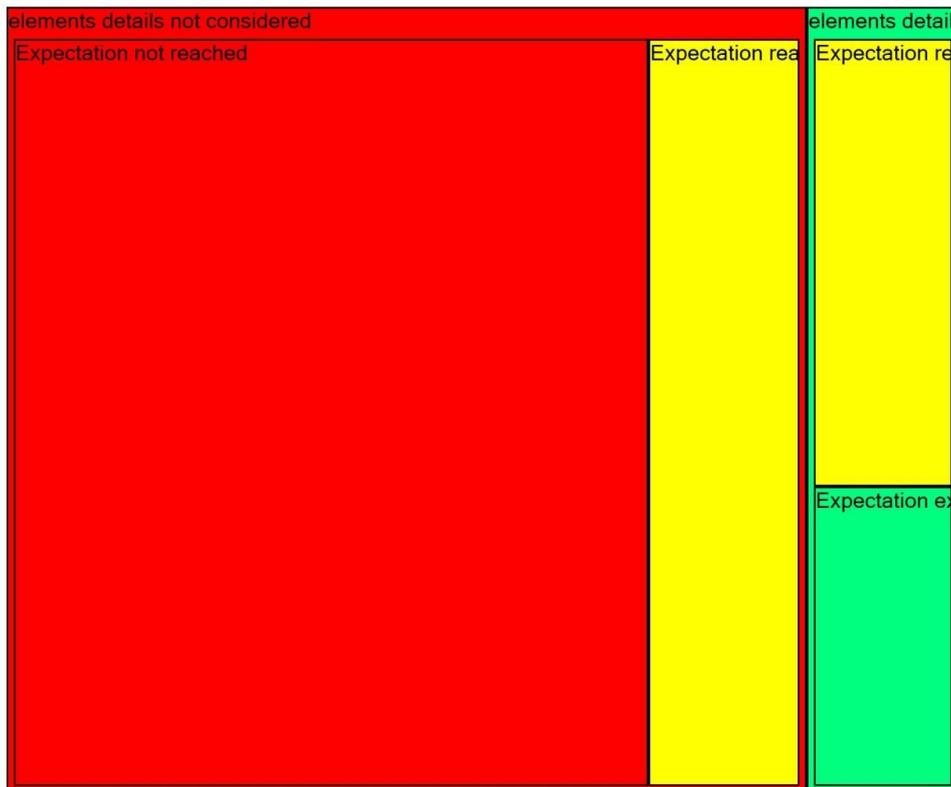


Figure 42. Tree Map 24. form and details considered and expectations

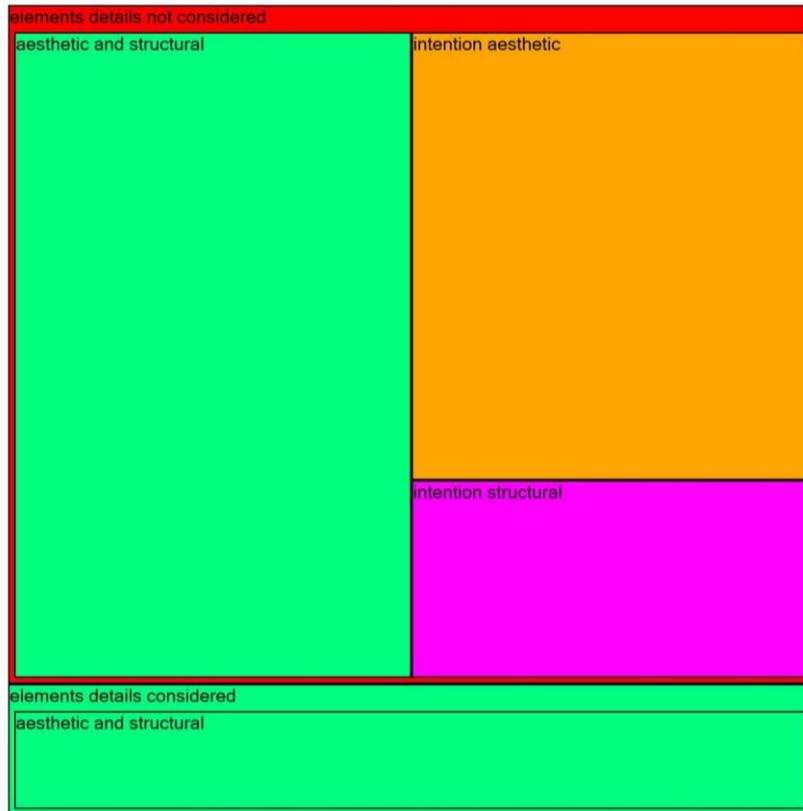


Figure 43. Tree Map 25. Formal intentions and concern on details

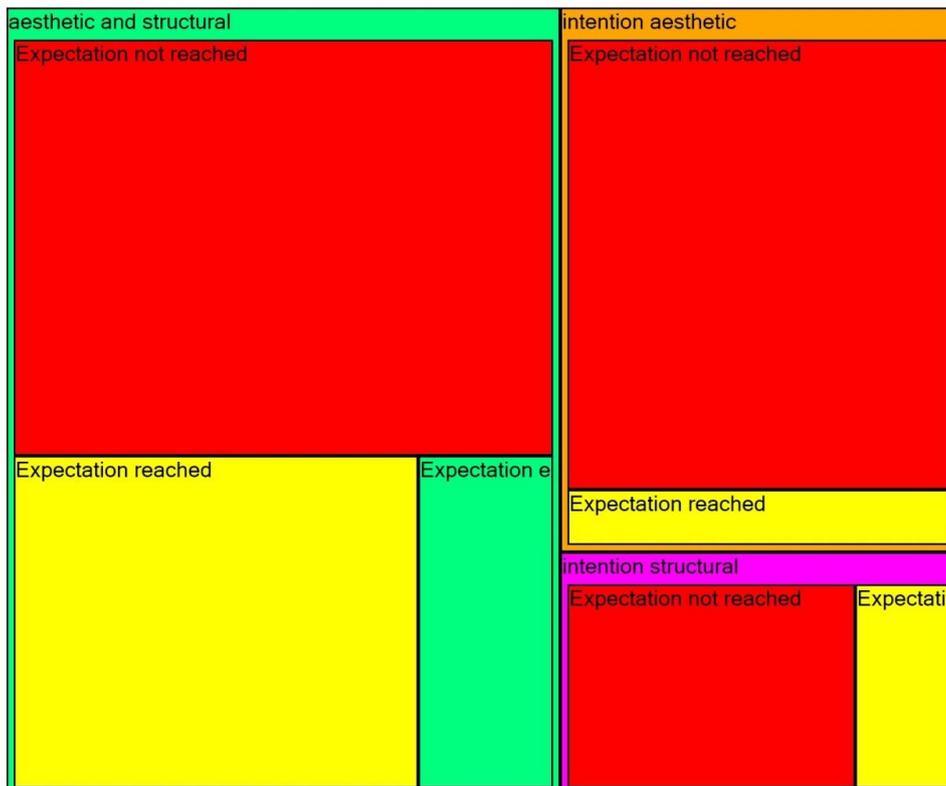


Figure 44. Tree Map 26. Formal intentions and expectation



Figure 45. Tree Map 27. Formal intentions, expectation and model stability

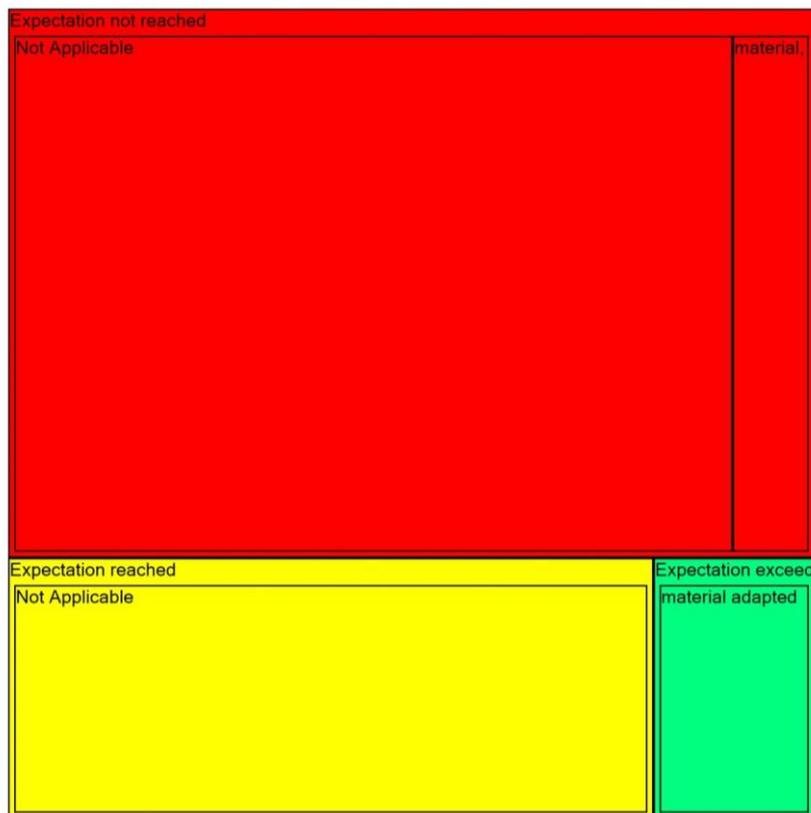


Figure 46. Tree Map 28. itens redesigned and expectations

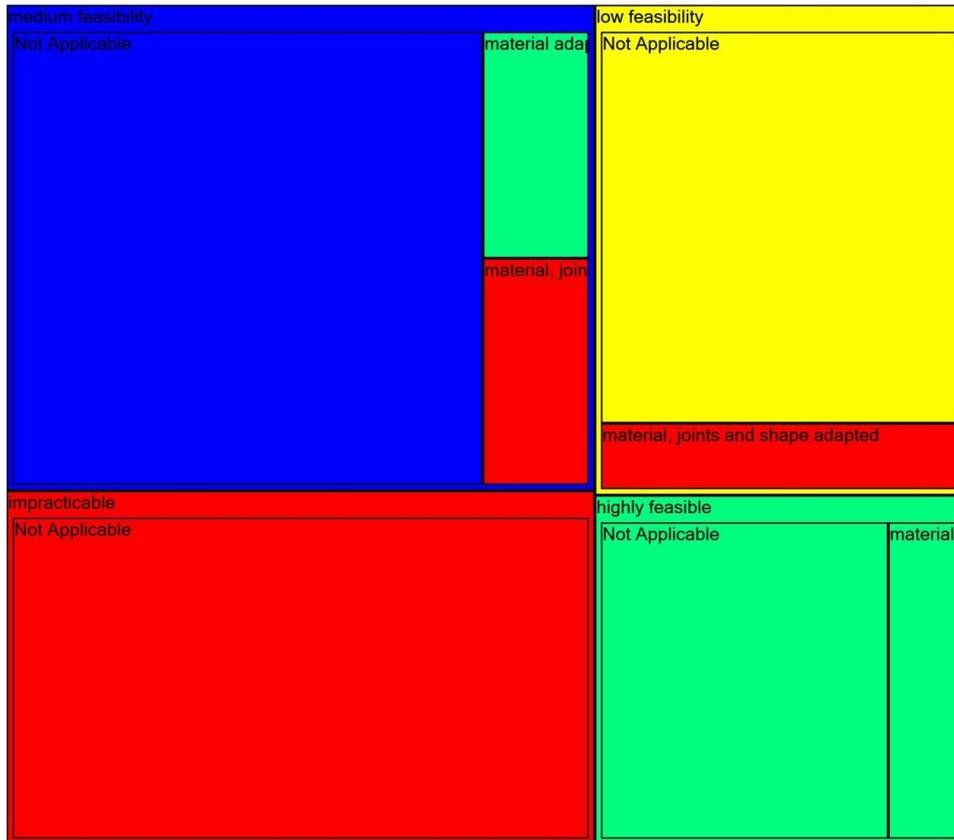


Figure 47. Tree Map 29. itens redesigned and feasibility



Figure 48. Tree Map 30. itens redesigned and manufacture skills

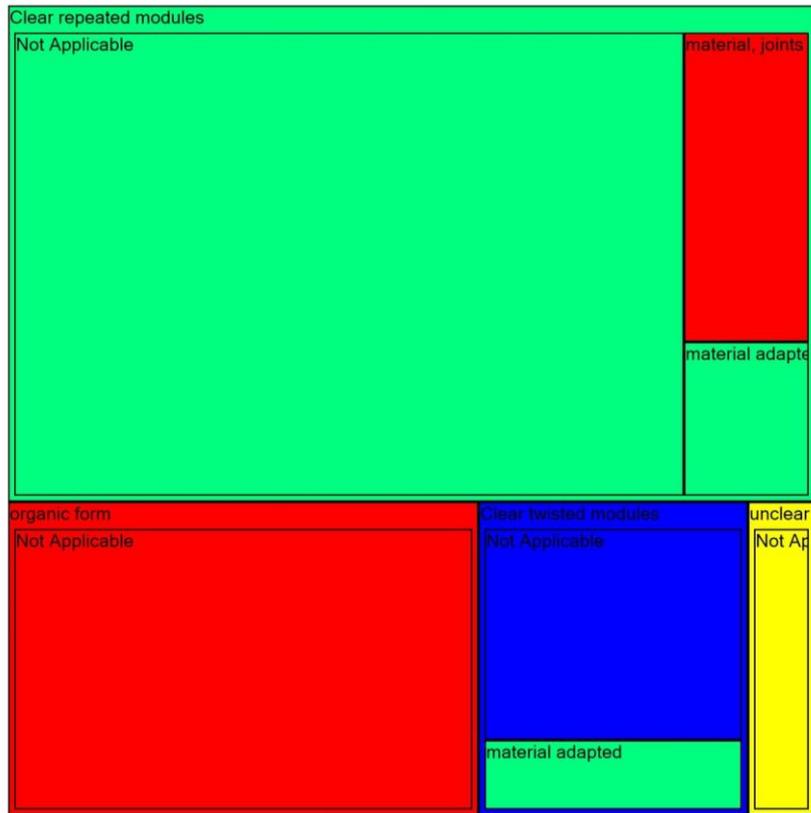


Figure 49. Tree Map 31. itens redesigned and modulation



Figure 50. Tree Map 32. itens redesigned, modulation and tridimensional composition

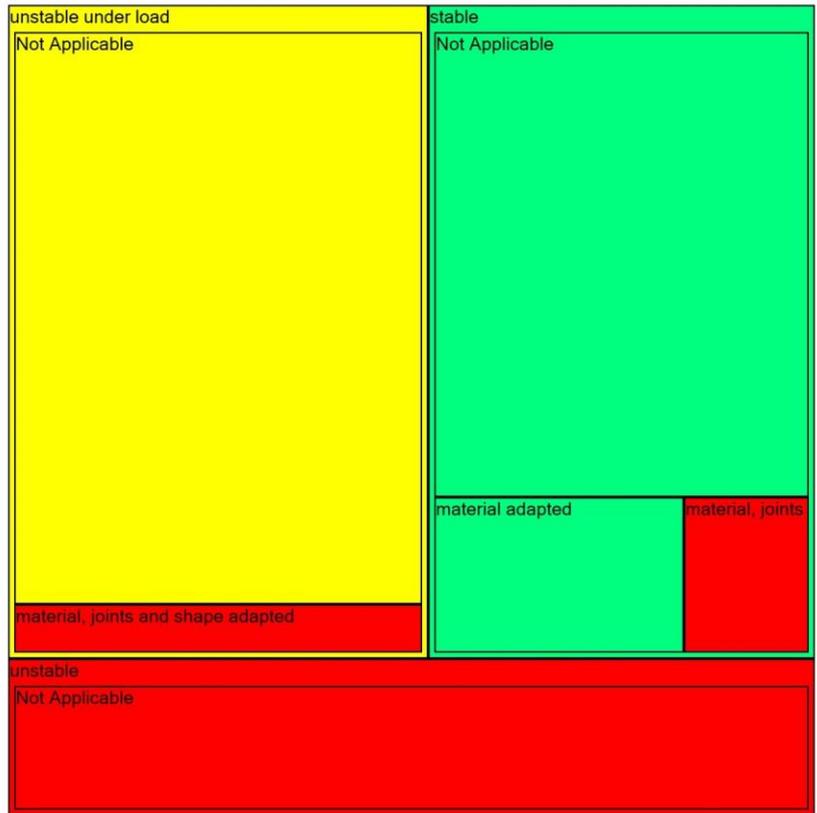


Figure 51. Tree Map 33. itens redesigned and stability

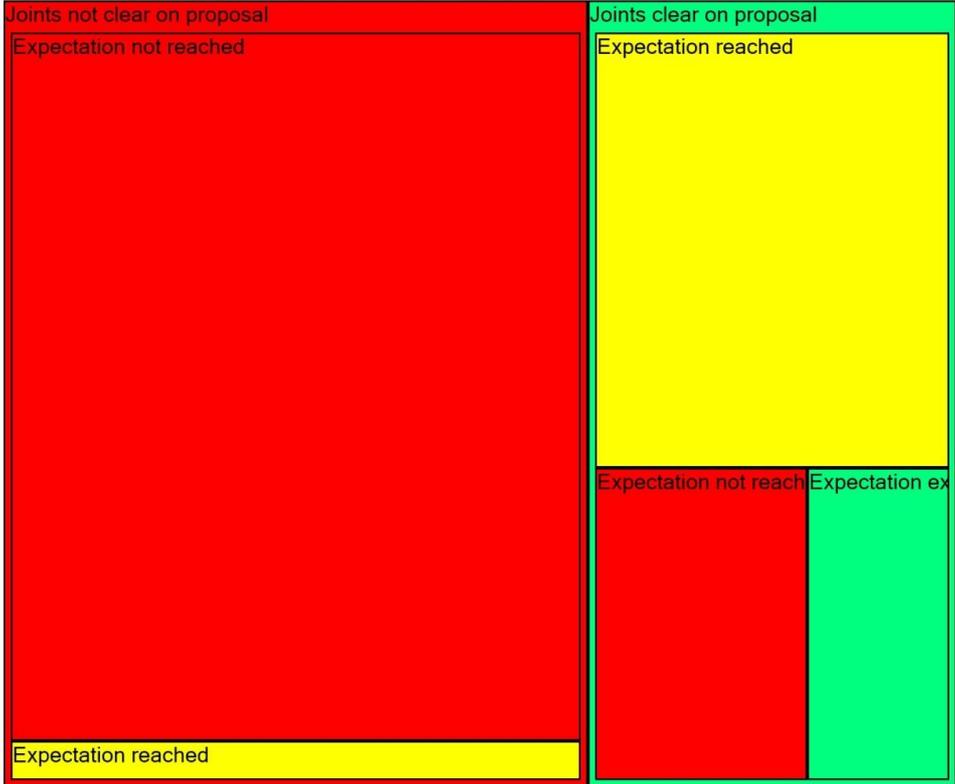


Figure 52. Tree Map 34. Joints and expectation

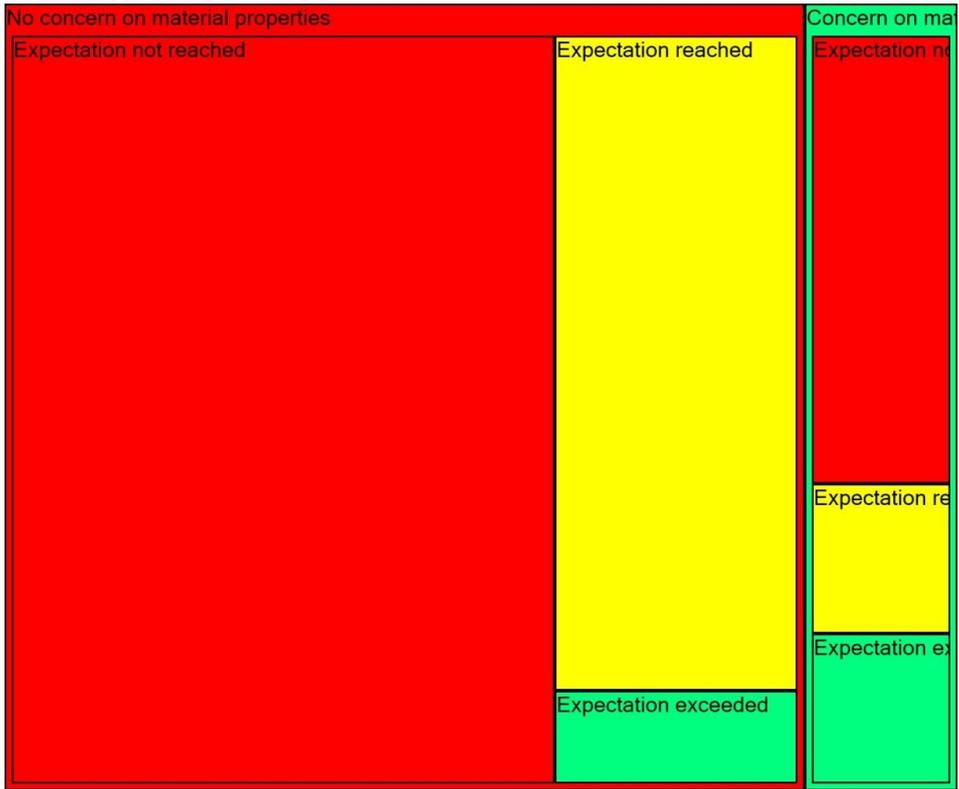


Figure 53. Tree Map 35. material properties and expectations

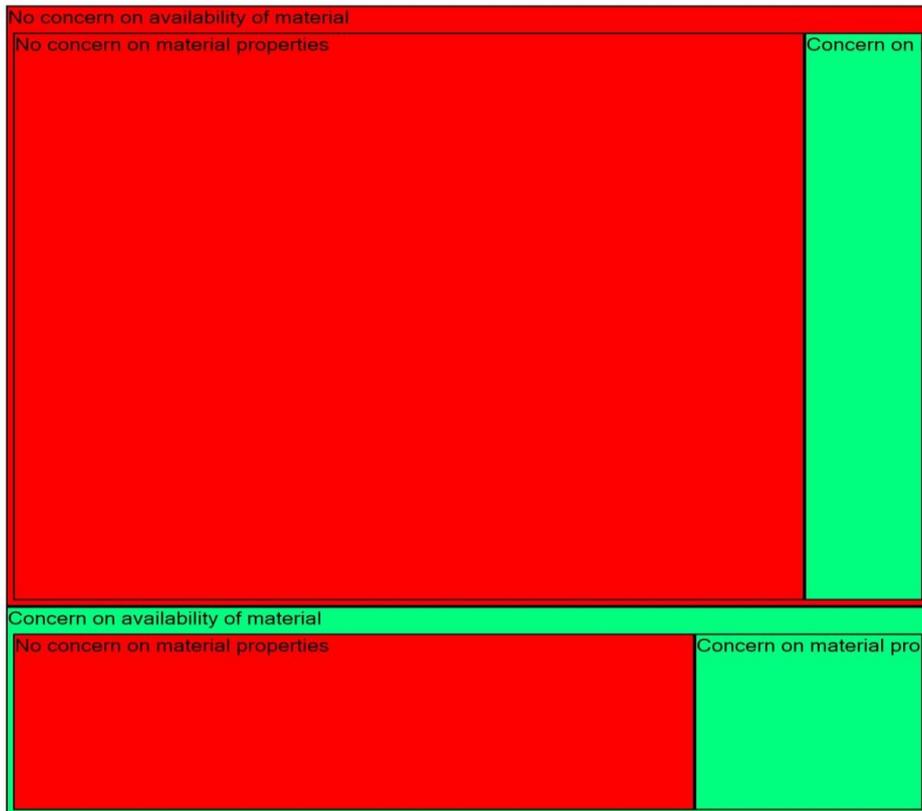


Figure 54. Tree Map 36. material properties and material availability

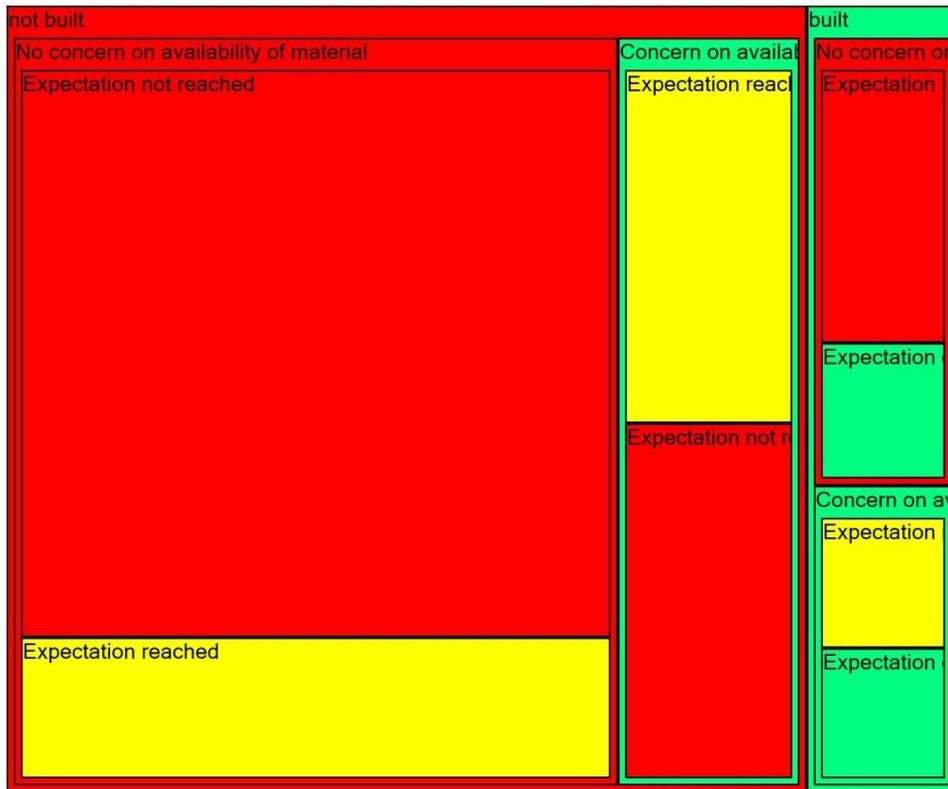


Figure 55. Tree Map 37. model built, concern on material availability and expectation

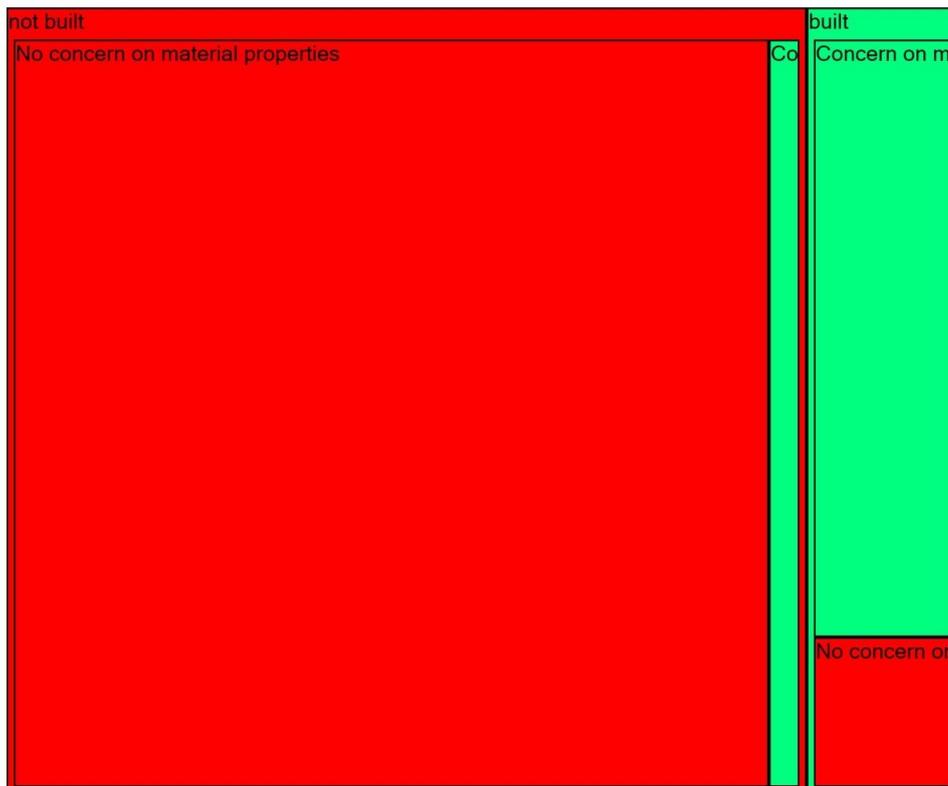


Figure 56. Tree Map 38. model built and concern on material properties



Figure 57. Tree Map 39. model built, connections intelligence and expectation

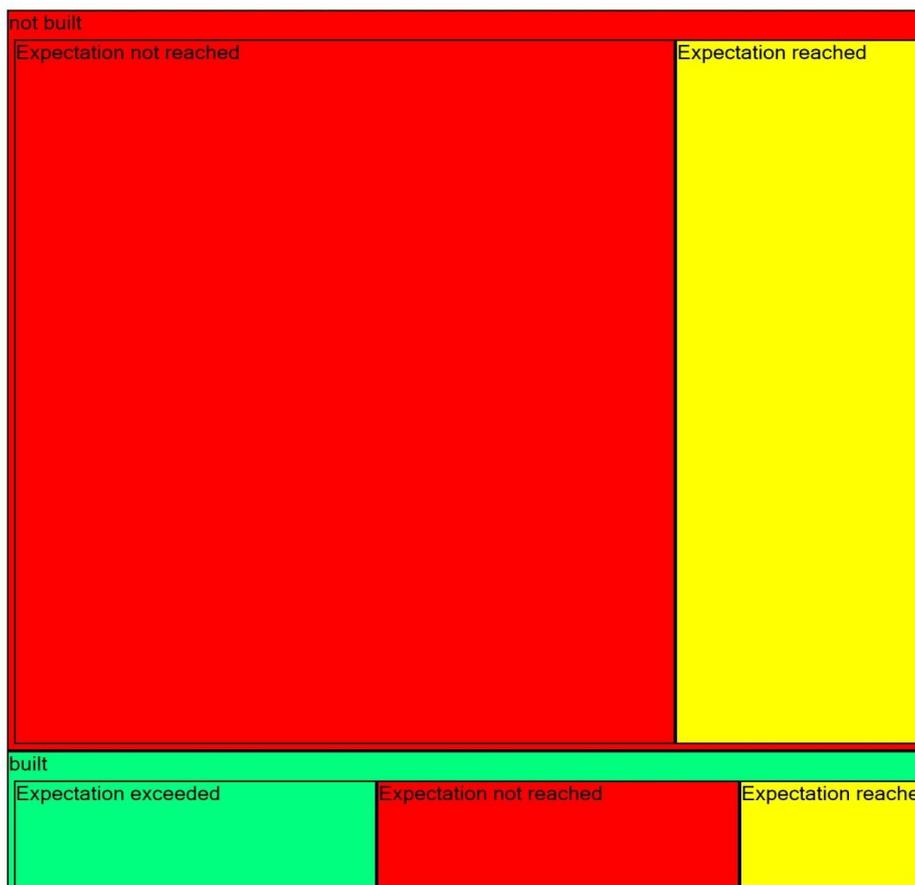


Figure 58. Tree Map 40. model built and expectations

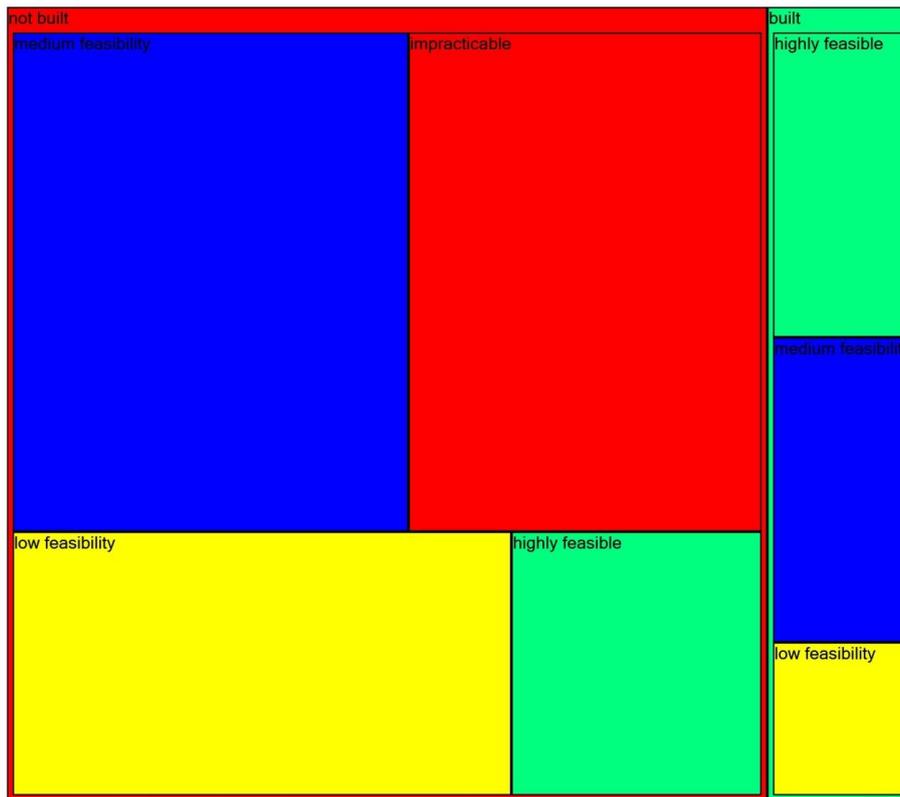


Figure 59. Tree Map 41. model built and feasibility

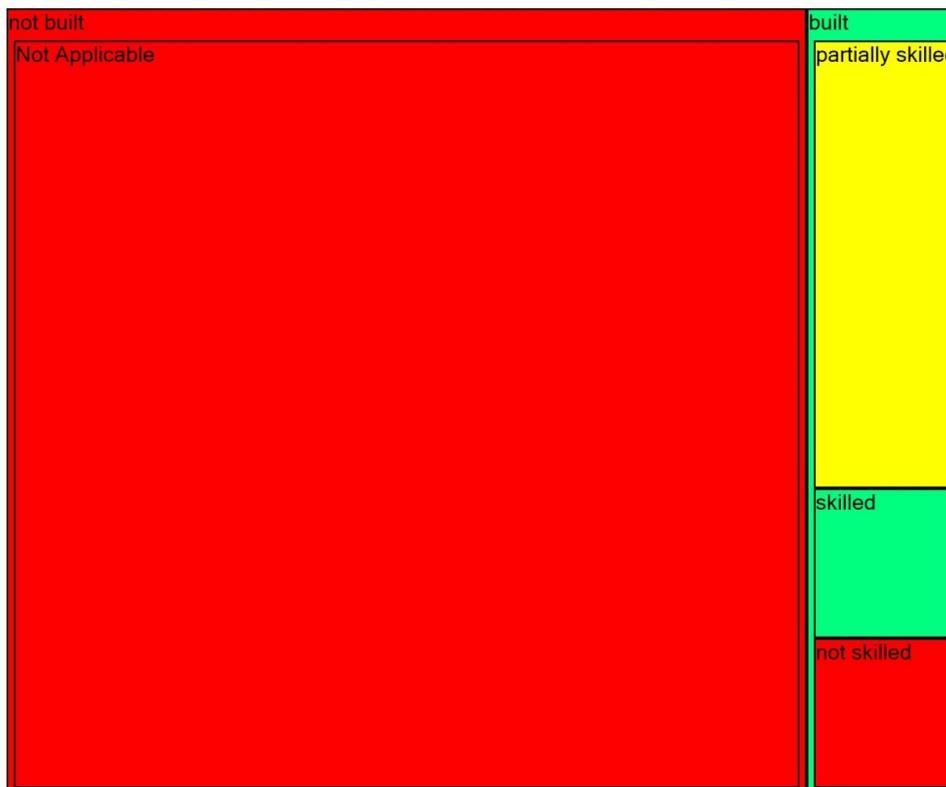


Figure 60. Tree Map 42. model built and manufacture skills

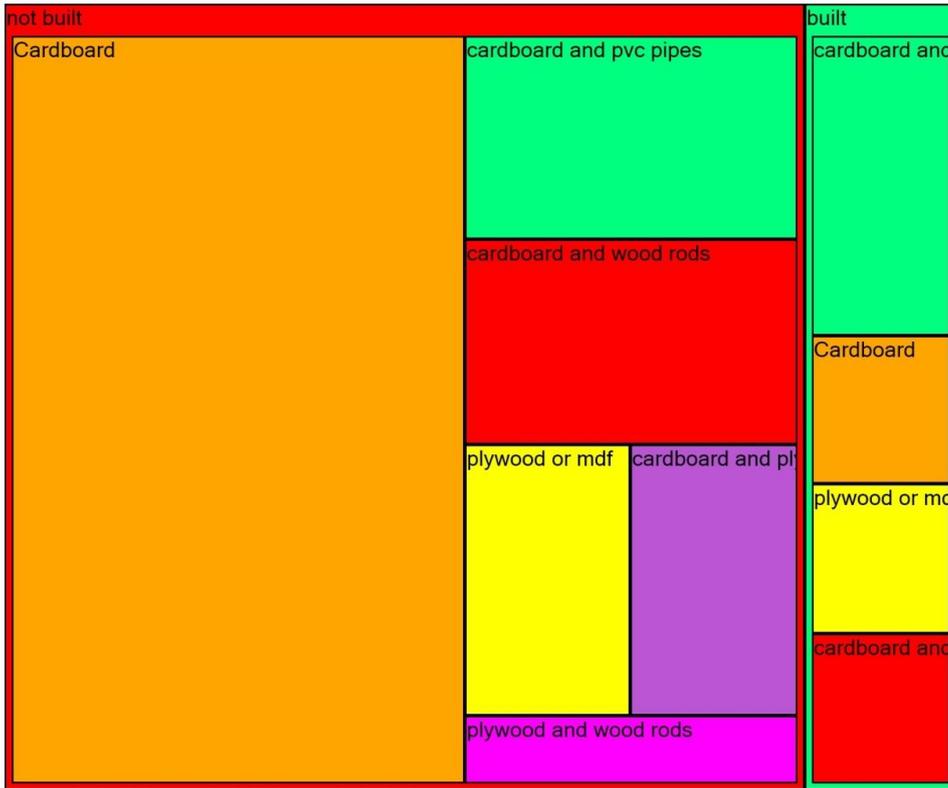


Figure 61. Tree Map 43. model built and model materials used



Figure 62. Tree Map 44. model built and reasons for redesign



Figure 63. Tree Map 45. model built and redesign level



Figure 64. Tree Map 46. model built, redesign level and reasons for redesign



Figure 65. Tree Map 47. model materials and connections intelligence



Figure 66. Tree Map 48. model materials and handleability



Figure 67. Tree Map 49. model materials and stability

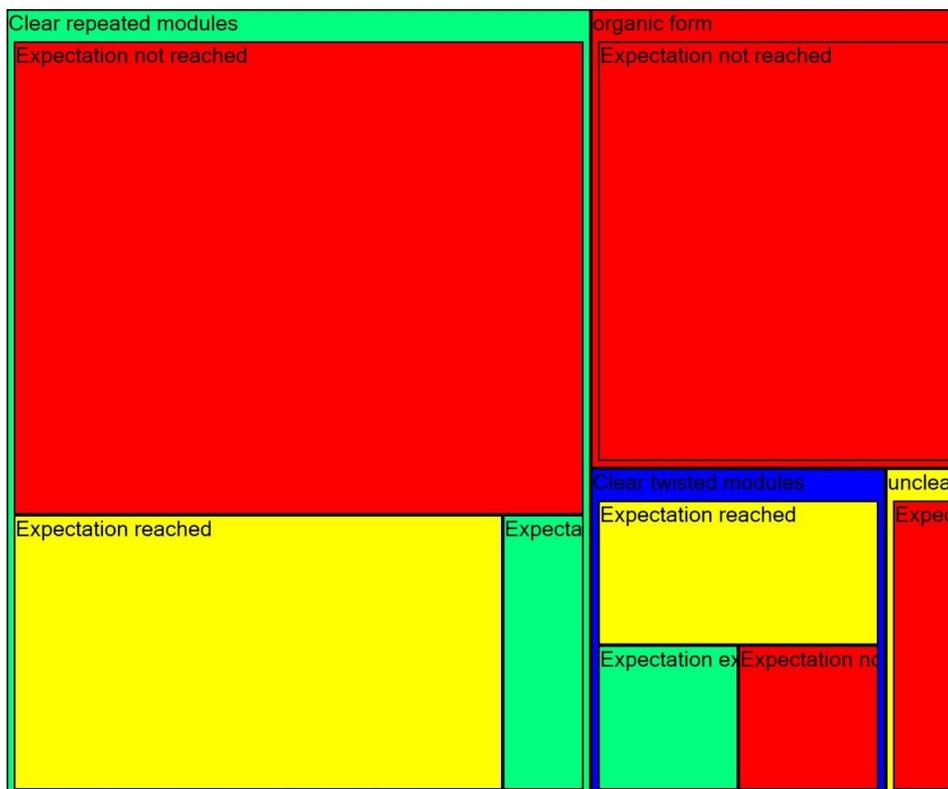


Figure 68. Tree Map 50. Modulation and expectation

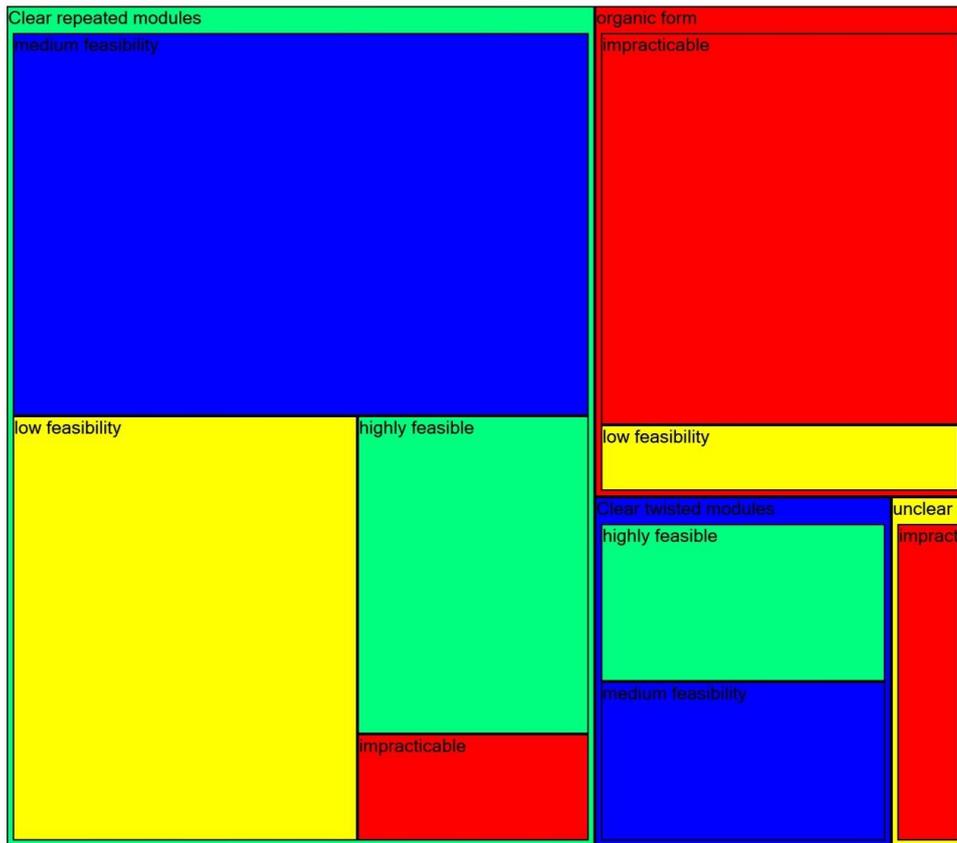


Figure 69. Tree Map 51. Modulation and model feasibility

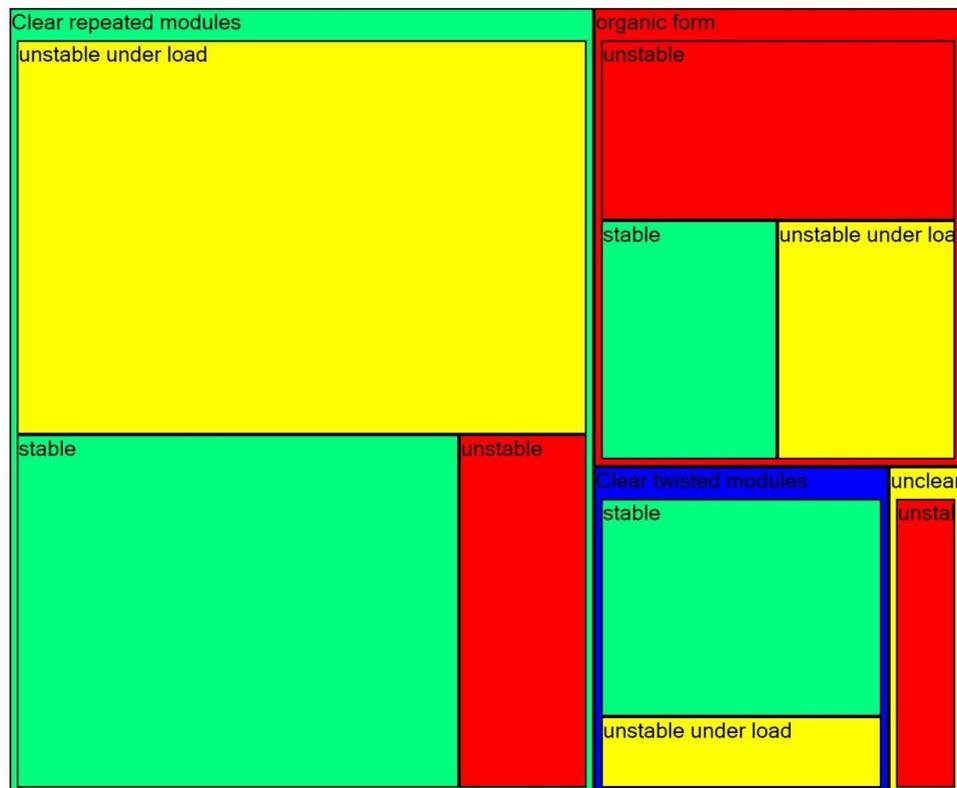


Figure 70. Tree Map 52. Modulation and model stability

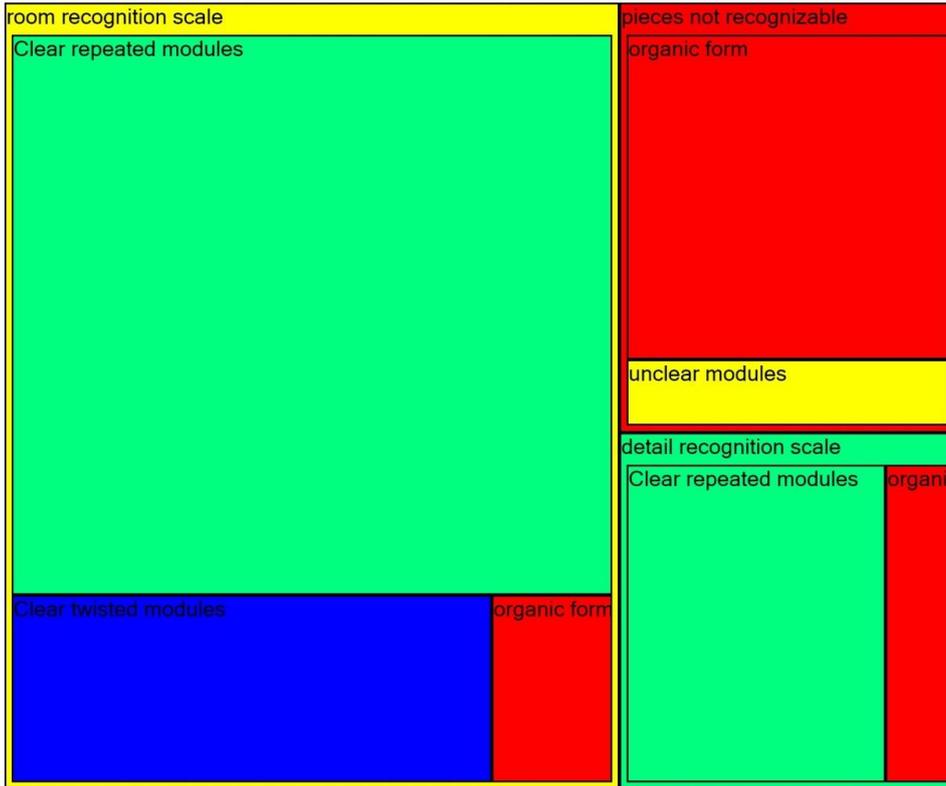


Figure 71. Tree Map 53. Modulation and recognition scale of the pieces



Figure 72. Tree Map 54. proposed joints and connections intelligence

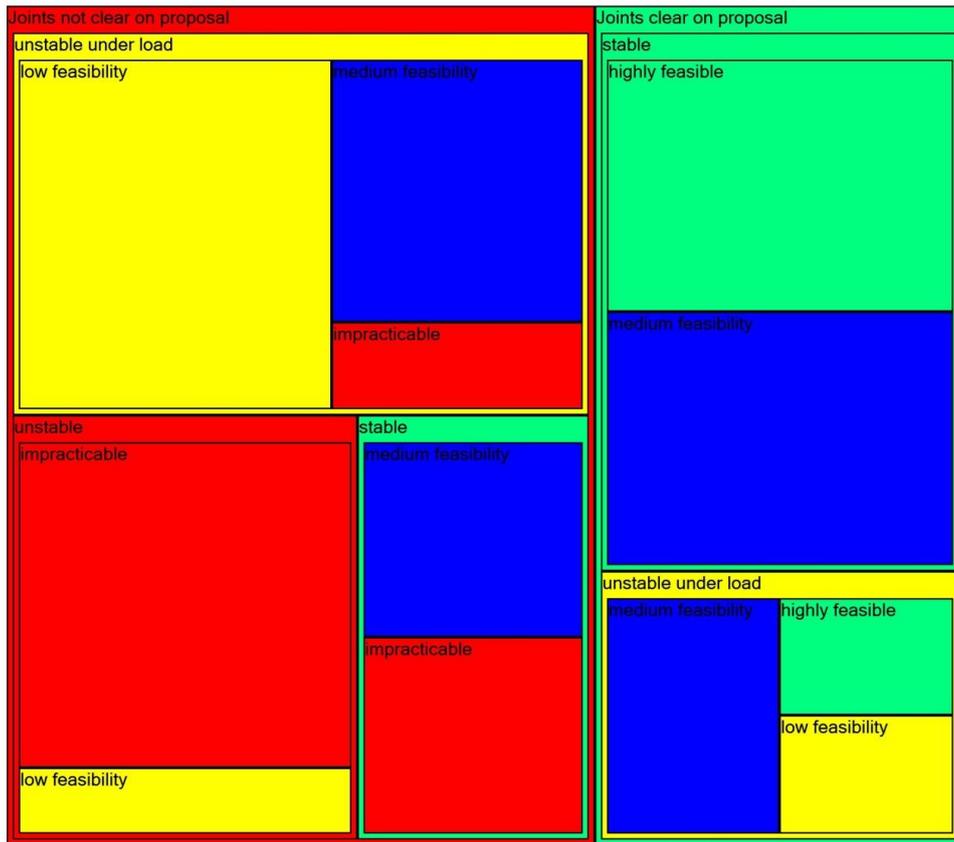


Figure 73. Tree Map 55. proposed joints, feasibility and stability



Figure 74. Tree Map 56. Recognition scale of the pieces



Figure 75. Tree Map 57. redesign level, reasons for redesign and tridimensional composition



Figure 76. Tree Map 58. redesign level, reasons for redesign and concept development



Figure 77. Tree Map 59. redesign level, reasons for redesign and connections intelligence



Figure 78. Tree Map 60. redesign level, reasons for redesign and documentation methods



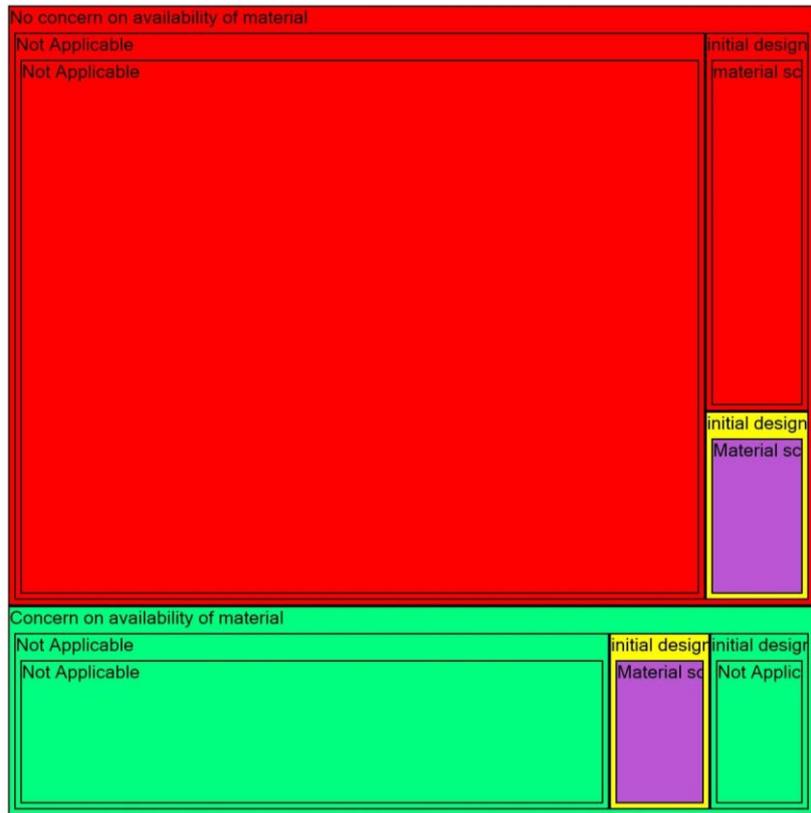


Figure 81. Tree Map 63. redesign level, reasons for redesign and material availability



Figure 82. Tree Map 64. redesign level, reasons for redesign and material details



Figure 83. Tree Map 65. redesign level, reasons for redesign and material properties



Figure 84. Tree Map 66. redesign level, reasons for redesign and model materials



Figure 85. Tree Map 67. redesign level, reasons for redesign and modulation



Figure 86. Tree Map 68. redesign level, reasons for redesign and proposed joints

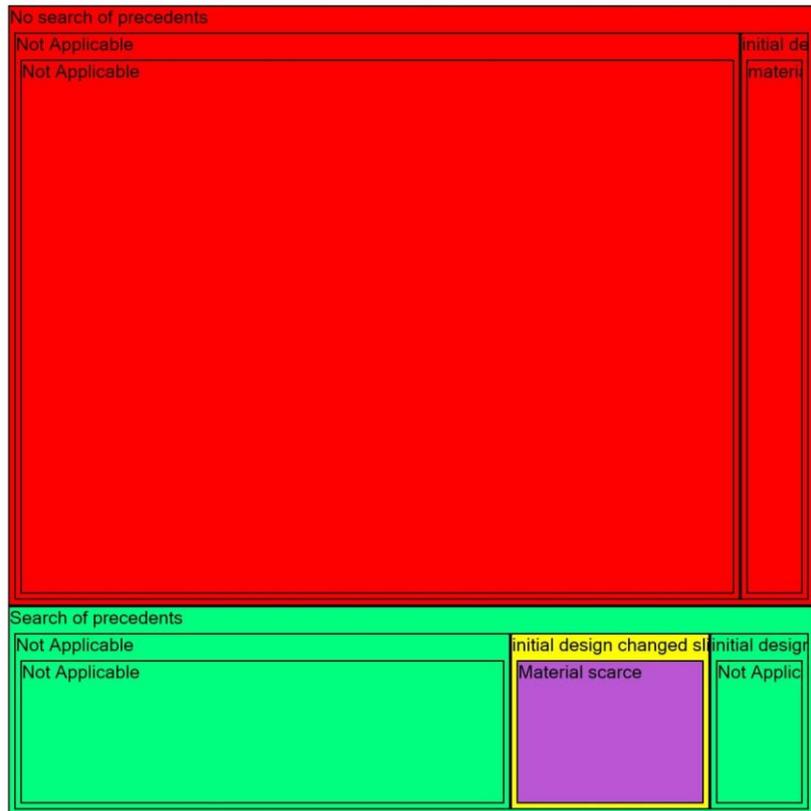


Figure 87. Tree Map 69. redesign level, reasons for redesign and search of precedents

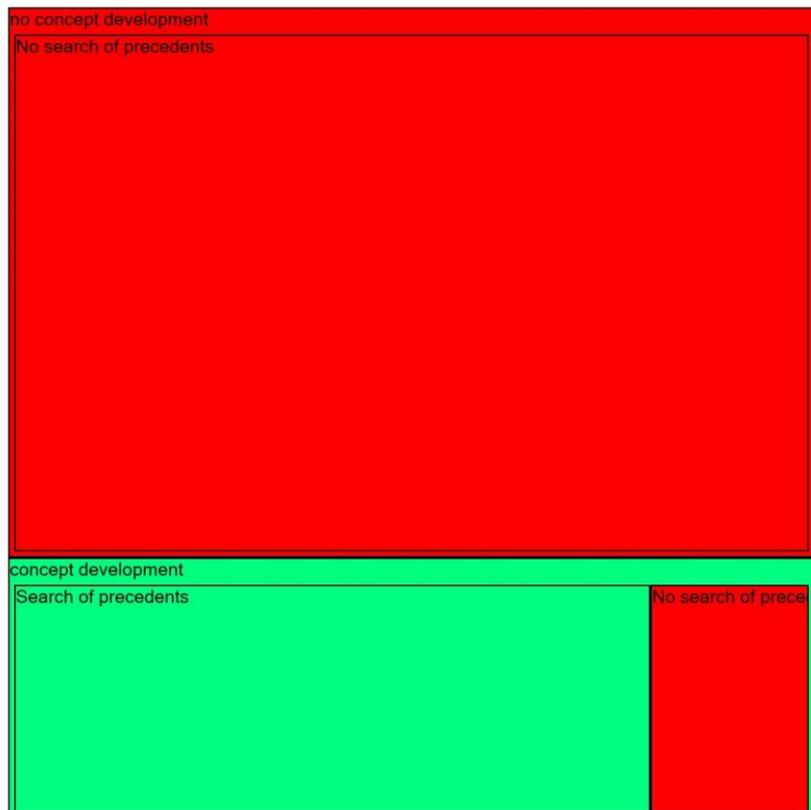


Figure 88. Tree Map 70. search of precedents and concept development

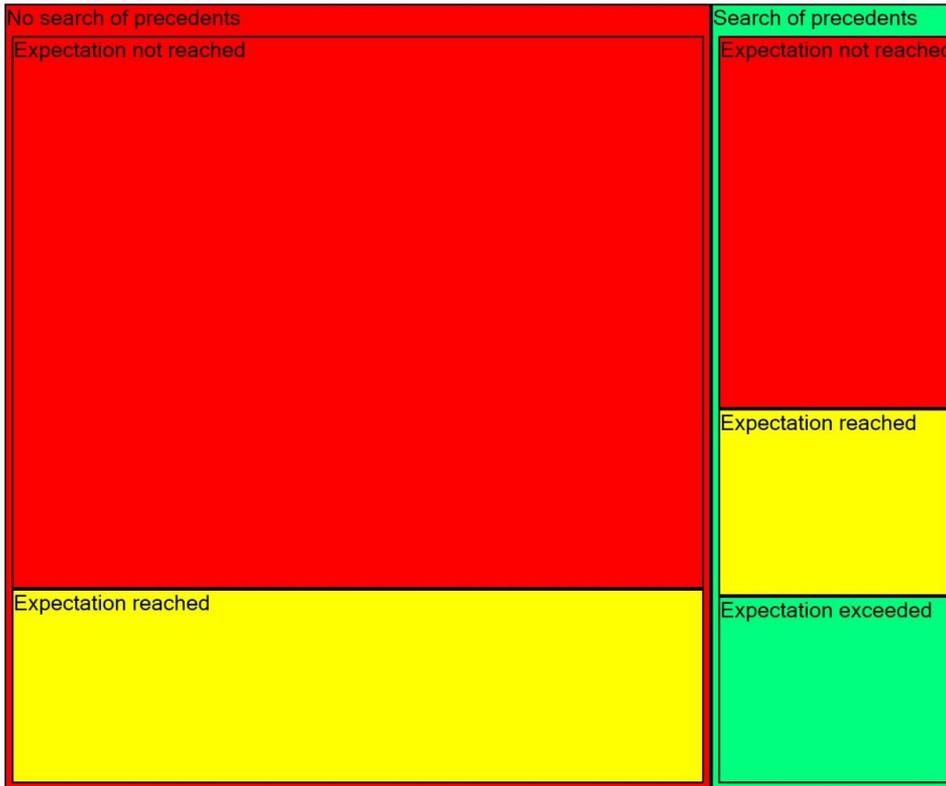


Figure 89. Tree Map 71. Search of precedents and expectation

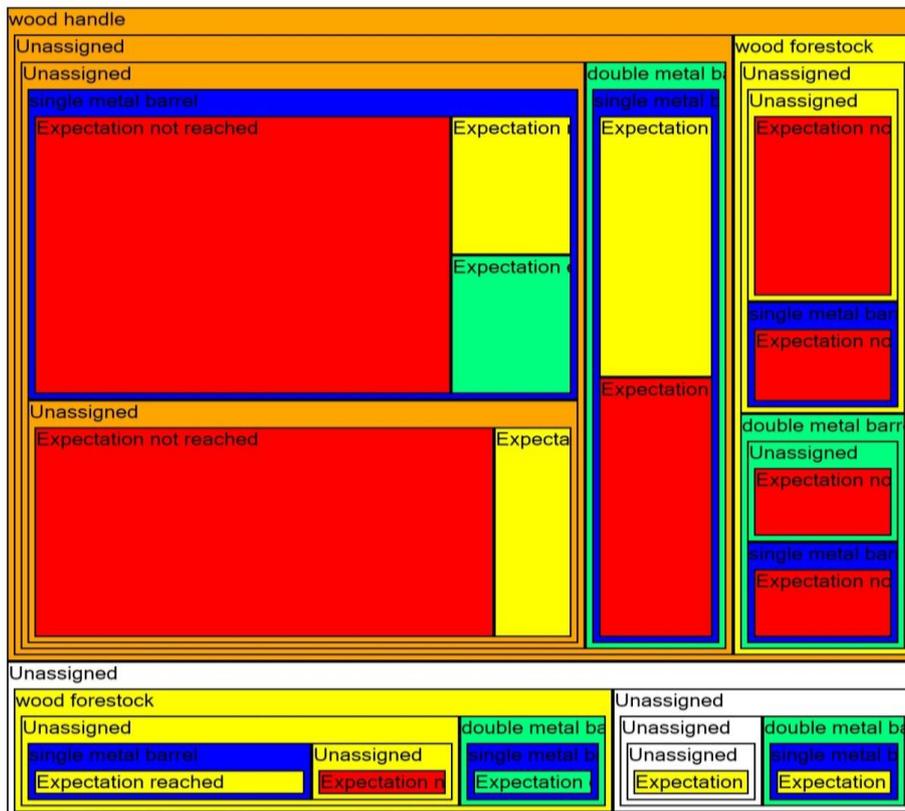


Figure 90. Tree Map 72. Types and expectations

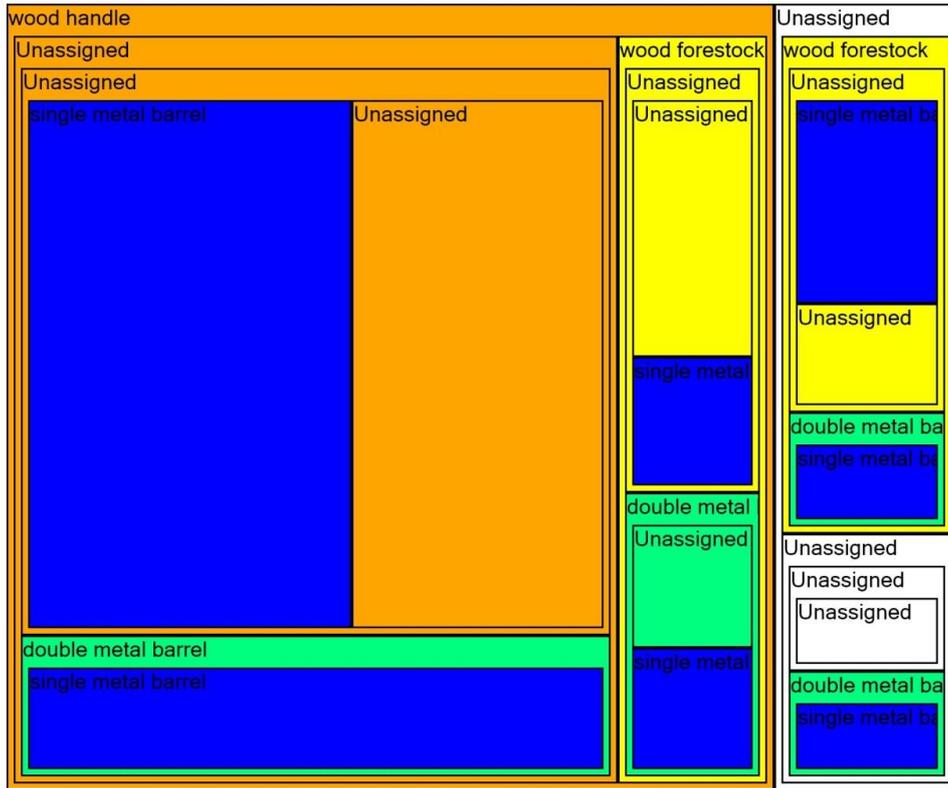


Figure 91. Tree Map 73. Weapon parts applied

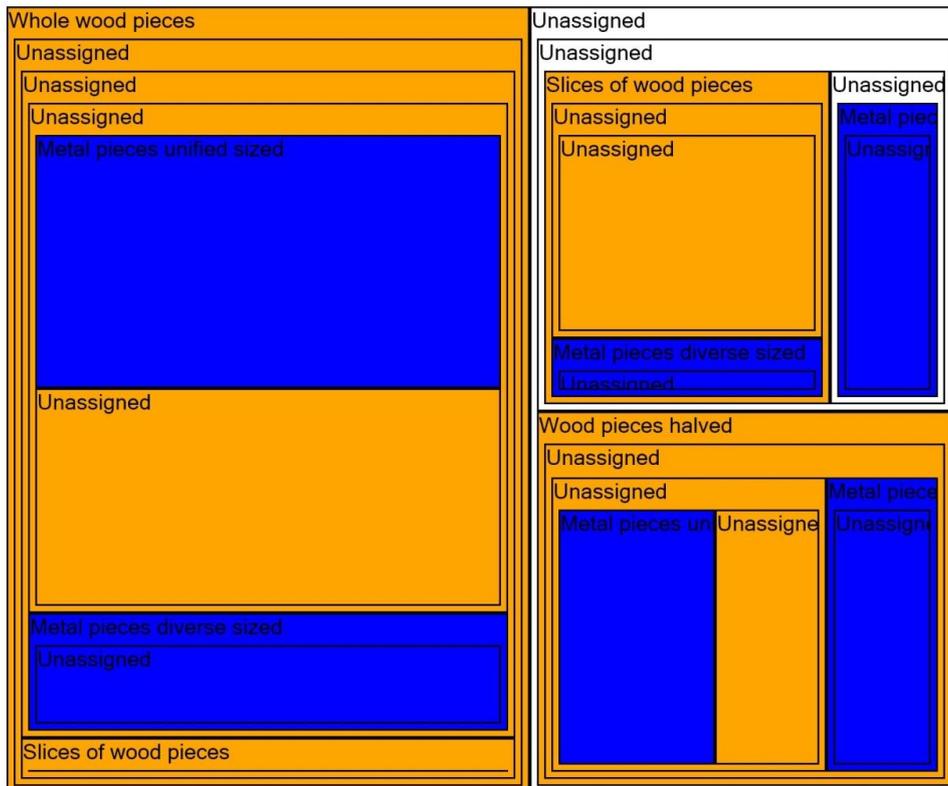


Figure 92. Tree Map 74. Weapon parts' cuts

**B12. Causality Table**

TREE MAPS	CAUSE	POTENTIAL EFFECT	
		POSITIVE	NEGATIVE
1	Hand drawing and hand drawing CAD based	tridimensional composition	
1	CAD drawing		bidimensional composition
2,3, 57	Tridimensional composition	expectations / stability/ high feasibility/ low redesign	
3	Bidimensional composition		instability infeasibility
4, 58, 69, 71	Concept development / search of precedents	expectations, low redesign	
4	No concept development		expectations
6, 59,7	Forced joinery		expectations / redesign /stability / feasibility
6, 59,7	Forms enhances connections and 3D connections	expectations/ low redesign / stability / feasibility	
8	Hand drawing/ CAD drawing / partial and not reliable		feasibility
8	Hand drawing CAD based complete and reliable	feasibility	
9	Hand drawing CAD based	stability	
9,22	CAD drawing		stability / feasibility
10	Documentation methods		expectations
11,12	Documentation complete	expectations/ feasibility	
11,12, 61	Documentation partial and not reliable		expectations / feasibility/ redesign
14	Combination of cuts		
15	Handleability		
16,18, 28	Material shortage and failed design/ Material, shape and joints redesigned		expectations
17	Skilled / partially skilled	expectations	
19	Pieces not recognizable		expectations
20,21	Expectations met or exceeded	stability /low redesign	
23	Expectations not met		feasibility
24	No consideration of elements details		expectations / mixed formal intentions
25, 63	Consideration of elements details	Aesthetic and structural models / low redesign	
26, 27	Aesthetic and structural models	expectations / stability	
27	Aesthetic models only		expectations / stability
29	Highly feasibly models	Redesign nil	
30	No manufacture skill		Material, shape and joints redesigned
31,33	Modulation and stability	Redesign low or nil	
34, 68	Joints unclear		expectations
35	No consideration of material properties		expectations
36,38	Consideration of material properties	built / low redesign	
37, 63	Consideration of material availability	expectations / redesign low	
39	Built / 3d connection and form enhances connections	expectations	
41	Unfeasibly		not built
47,48,49	Cardboard as only material	connections	handleability / stability
50,51, 67	Modulation	expectations / feasibility / stability/ built	
54,55, 68	Joints clear on proposal	intelligent connections/ stability / feasibility / low redesign	
62	Aesthetic and structural formal intentions	low redesign	

# Appendix C

## Skilful Rematerial Interaction

Appendix C refers to the semi-structured interview with Phooey Architects and Multiplicity. The questionnaire used to guide the conversation is firstly presented, followed by the relevant chunks of talks coded.

The NVivo project file containing raw sources, such as the complete transcriptions and node structure to the project are available in the shared folder hosted by Dropbox service, accessible through the following link:

<https://www.dropbox.com/sh/vpy0r00y657x74o/AAC5t2XVY9oev7mian0x9S0da?dl=0>

### **C1. Semi structured interview: Phooey and Multiplicity**

(The questions were only intended to guide the interview. They have changed according to the opportunities and the flow of the conversation)

1. How did Superuse Studios start? Did you perform mod before it was created?
2. What is the profile of your clients?
3. What is the profile of the working team?
4. In which stage of the design process does each expert work?
5. Do you follow any workflow for your projects? Please describe.
6. How does Superuse Studios harvest resources for the projects?
7. Which information is important to observe and learn from the material before starting the design process? Do you organize this information? How?
8. Which/how digital tools are used during the design process?
9. How common is redesign when building starts?
10. Do you perform any physical test with the material during the design process?
11. How is the design documented/presented?
12. Each project is customized so it demands different skills and tools to be built. What is the approach for this question?

## C2. Coding 1: Multiplicity

Page 1: Commented [NP1] Nicole Pereira 2/08/2016 3:25:00 PM

Sioux and I used to walk around a lot and we've just found things on the ground, ju pick them up and go, they're beautiful

Discovery

Page 1: Commented [NP2] Nicole Pereira 2/08/2016 3:26:00 PM

finding their intrinsic beauty and discovering things, understanding materials

Discovery

Page 1: Commented [NP3] Nicole Pereira 2/08/2016 3:27:00 PM

If you got a beautiful piece like this and what can you do with something like this? An then we realise that you can make a door handle (...) the first thing when you're entering then you open it.

The entry, the opening. Discovery

Page 2: Commented [NP4] Nicole Pereira 2/08/2016 3:29:00 PM

we said the guys why are you burning this (the timber)? They said, you know, we can't do anything else, what you can do with it? We said, look we like this and this and this (...) So we made these two into bench seats and then another piece we made that into a part a balustrade. Discovery, define, material saved for later

Page 2: Commented [NP5] Nicole Pereira 2/08/2016 3:31:00 PM

we started realizing how you have to deal with recycled materials (...) they are not standard, sizes, all the fixings. You have to rethink about how you put them together. And most of the ways that we put them together were really really simple.

Discovery, define, develop, delivery

Page 2: Commented [NP6] Nicole Pereira 2/08/2016 3:34:00 PM

the materials and methodology we used, because we are not builders, to do ow, was very simplistic things, you kn like how do you fit this thing to that thing, the connections and so

Develop, delivery, connections, skills

Page 2: Commented [NP7] Nicole Pereira 2/08/2016 3:36:00 PM

a lot of people think that they have to turn them into something that they're not. Where if you simply have a roll piece of timber you've got to look for the way of connecting it to the door or to

wherever you want to, and using simple use simple ways of connection Discovery, define, develop, delivery

Materiality, Material information

Page 3: Commented [NP8]	Nicole Pereira	2/08/2016 3:37:00 PM
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So the few bits and pieces we had we realize have to be stuff that is really easy to p used a lot of aluminium, because steel is really hard to cut

Define, develop, delivery, tools, skills

Page 3: Commented [NP9]	Nicole Pereira	2/08/2016 3:39:00 PM
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being resourceful in the process and thinkingde the normal

outs Define, develop, delivery, tools, skills

Page 3: Commented [NP10]	Nicole Pereira	2/08/2016 3:40:00 PM
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I started when I had three (fluorescent lamp covers), what can I do with this? And then I was... I had twenty, and then I had thirty and then I end up having fifty of them. One of the most interesting thing about you recycling materials is repetition

Discovery, define, repetition, patterns

Page 3: Commented [NP11]	Nicole Pereira	2/08/2016 3:42:00 PM
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If you've got one (piece of material) (...) it's ve you can turn them into multiple, a wall or a ceiling

Discovery, define, repetition, patterns

Page 4: Commented [NP12]	Nicole Pereira	3/08/2016 2:47:00 PM
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as soon as you can start to get a reputation to get clients with money, then they're not as

open Define, client profile

Page 4: Commented [NP13]	Nicole Pereira	3/08/2016 2:48:00 PM
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They (the clients) have good eyes. It is just about seeing another life in something and a

potential. Discovery, client profile

Page 5: Commented [NP14]	Nicole Pereira	3/08/2016 2:49:00 PM
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that was down at a local park, just around the corner... and it was just about to fall off and it had been there for years and years and everyone who passed would ignore it. Sioux and I would pass and say that is so beautiful. Discovery, materiality

Page 5: Commented [NP15]

Nicole Pereira

3/08/2016 2:50:00 PM

T: there are certain people that can walk around they won't look at it. most people will possibly think it's trash, and

that's beautiful, where

S: Some people don't have vision.

Discovery, materiality

Page 5: Commented [NP16]

Nicole Pereira

3/08/2016 2:51:00 PM

that's part of your training that you can visualise. So that is very important. Still most architects, they can't.

Discovery, materiality, skills

Page 5: Commented [NP17]

Nicole Pereira

3/08/2016 2:52:00 PM

They (architects) would buy a sixteen century French dining table (...) because it has got rustic beauty (...) while they could just do the same with the pieces of timber that they just walked passed in the street. It is quite confounding.

Discovery, ROD obstacles

Page 5: Commented [NP18]

Nicole Pereira

3/08/2016 2:55:00 PM

S: It is an effort, but it is a joy when we get into it. It is a nice part of our leisure time.

the first time (...) It is actually

Discovery, motivators

Page 6: Commented [NP19]

Nicole Pereira

3/08/2016 2:57:00 PM

To pay somebody to do that, it is a different thing. That is where it becomes quite difficult, when you're paying labour, but if you're doing it because you come across things and it's a labour of love then you can more readily achieve using them in buildings.

Discovery, define, develop, motivators

Page 6: Commented [NP20]

Nicole Pereira

3/08/2016 2:58:00 PM

if I see a material, I want not one, I want lots (...) so I know if there is enough to achieve

something Discovery, define, material information, quantity

Page 6: Commented [NP21]

Nicole Pereira

3/08/2016 3:00:00 PM

We do it from a sort of modernist aesthetic because we're looking at horizontals and verticals, but other people do it from a more earthy, grassroots, timber and marbrick sort of aesthetic. Discovery, Define, Develop, concepts, forms

Page 6: Commented [NP22]

Nicole Pereira

3/08/2016 3:01:00 PM

recycling generally has been seen as the domain of organic, hippies. So a lot of people think, oh no I don't want second hand materials because it has hippie kind of, and we're really interested in turning out those heads a little bit. You could have really beautiful modernist buildings with recycled materials as well. Discovery, define

Page 7: Commented [NP23]

Nicole Pereira

5/08/2016 1:03:00 PM

you can take all your aluminium cans to the recycle and they crush them up and then it comes back. But then it comes back to you as a product. You don't have any control on the product. Whereas if you can do it yourself, you can control, you know, the colour and pattern, the lumpiness (...)

Discovery, define, materiality

Page 7: Commented [NP24]

Nicole Pereira

5/08/2016 1:04:00 PM

We started getting known by people who recycle materials, so beforehand it was us going out to find stuff, but it got to the point that people were bringing us stuff as well

Discovery, harvesting

Page 7: Commented [NP25]

Nicole Pereira

5/08/2016 1:05:00 PM

We've got a large warehouse at the back so we could store things, but if you are a normal architect, you just can't Discovery, define, storage, material saved for later, limitations

Page 7: Commented [NP26]

Nicole Pereira

5/08/2016 1:06:00 PM

but if I'm using recycled material I've got to know exactly what it is, I've got know dimensions of what they exact di are because, you know, sometimes you can't reuse them Discovery, define, Material Information

Page 7: Commented [NP27]

Nicole Pereira

5/08/2016 1:07:00 PM

So the effort when I'm designing is like, I have to know exactly each size of everyone, how many I have got, exact thickness of it. Because they vary, because recycled material varies a lot. So you've got to document. I've got a list of everything stored on the back.

Discovery, Define, Develop, Material Information, Documentation

Page 8: Commented [NP28]

Nicole Pereira

5/08/2016 1:08:00 PM

Architect, architect, graduate architect, architect and an interior designer  
student Team profile

Page 8: Commented [NP29]

Nicole Pereira

5/08/2016 1:09:00 PM

Everyone in the office, everyone will have a project that they are basically sitting on. Sioux and I will float between the projects (...) But, generally, we sort of developed a system of how we design and we have a sort of system of how we document as well.

Team profile, define, develop, documentation, process

Page 9: Commented [NP30]

Nicole Pereira

5/08/2016 1:11:00 PM

Some decisions need to be on site. Most of them not... most of them we try to document everything Define, Delivery, documentation, redesign

Page 9: Commented [NP31]

Nicole Pereira

5/08/2016 1:12:00 PM

So we give them a set of documents. And I believe those documents cover as much as I possibly can Define, Delivery, documentation, redesign

Page 9: Commented [NP32]

Nicole Pereira

5/08/2016 1:13:00 PM

So we try to make that nearly all the decisions are made. Occasionally, there will be something we're not sure how to do, so then we circle and note builder to talk to the architect when you get to this point but, generally, if you using recycled materials, we try to work out where they fit, how they fit together, what structures it is needed; we try to design everything before

Define, Delivery, documentation, redesign

Page 9: Commented [NP33]

Nicole Pereira

5/08/2016 1:14:00 PM

we will do them (the clients) often lots and lots of designs

Define, develop

Page 10: Commented [NP34]

Nicole Pereira

8/08/2016 1:29:00 PM

We take it to planning to get approvals and then we start, once we've got all that into, then we start looking at the internals and we do very detailed drawings

Define, develop, Workflow, detail, documentation

Page 10: Commented [NP35]

Nicole Pereira

8/08/2016 1:30:00 PM

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will take every room up to one to twenty. We'll draw every wall and start making decisions to talking about reusing of materials and start

Discovery, Define, develop

Page 10: Commented [NP36]

Nicole Pereira

8/08/2016 1:32:00 PM

we'll reuse as much as we can from the existing house

Discovery, Define, Develop, Delivery, materiality

Page 10: Commented [NP37]

Nicole Pereira

8/08/2016 1:33:00 PM

during demolition, materials come up. And then we bring them back here, and then we put them into another job. And that is quite labour intensive.

So, ideally, what we'd like to do is what is on site, we stack and leave on the site. And we repurpose it on site (...)

Discovery, define

Page 10: Commented [NP38]

Nicole Pereira

8/08/2016 1:35:00 PM

Because what is happening is that then we end up with lots of stuff we're storing where we don't need to store it if we can reuse it again.

Saved for later

Page 10: Commented [NP39]

Nicole Pereira

8/08/2016 1:36:00 PM

it's just so easy just to go to Bunnings and buy a from China.

nd trimmed. Brought

Materiality, Discovery

Page 10: Commented [NP40]

Nicole Pereira

8/08/2016 1:38:00 PM

Some builders actually like to work with recycled material, but some don't. So something that we have found is that if we can have the structure basically new and then we can add the recycled materials in afterwards, it makes it easier for builders.

Develop, delivery, maker, materiality

Page 11: Commented [NP41]

Nicole Pereira

8/08/2016 1:40:00 PM

You need to know the sizes. () I usually have an idea of how sturdy they are, because the materials they might get old, get brittle or damaged. So generally I try to get an idea of what condition they're in. How many I've got. All that kind of thing.

Discovery, material information

Page 11: Commented [NP42] Nicole Pereira 8/08/2016 1:42:00 PM

Tim shows his inventory of material. Very complete information. Timber, marbles, glasses) e, made manually with drawings, dimensions and other

Material information, documentation

Page 12: Commented [NP43] Nicole Pereira 8/08/2016 1:43:00 PM

We also do a lot of sketches (besides 2D in AutoCad). If you do hand sketches of something you've actually got to work it out and know that actually works but when you're working with detailing on computers sometimes looks good and you can't just stand it all. It is about tactility.

Develop, Delivery, Digital tools, documentation

Page 12: Commented [NP44] Nicole Pereira 8/08/2016 1:44:00 PM

On the computer, somehow, things seem to be recycled, they don't necessarily work hey're not perfect and

Develop, Delivery, Digital tools, documentation

Page 12: Commented [NP45] Nicole Pereira 8/08/2016 1:46:00 PM

we have a strong connection as an office to the builders and the building process. And I know there are a lot of architects out there and a lot of recent graduates that have no idea about the building process. Develop, Delivery, design and maker

Page 12: Commented [NP46] Nicole Pereira 8/08/2016 1:47:00 PM

We are very interested in materiality (...) and how it is going to be used. And we're very interested in how to build because, I can do a detail that looks beautiful, but actually can't be built. Because the builder can't get into fix things... or he probably can, but it will take ages.

Develop, Delivery, design and maker, connections redesign

Page 12: Commented [NP47] Nicole Pereira 8/08/2016 1:49:00 PM

The builders are frightened enough of using recycled materials and how they are going to put them together. So they want it to be pretty simple. to p

Develop, delivery, connections

Page 12: Commented [NP48] Nicole Pereira 8/08/2016 1:51:00 PM

We like industrial buildings. And if you actually look closely, industrial buildings are put together in a very simple format, and they use lots of angles, they just screw things together, is very rudimentary. But, if you stand back, they're really beautiful

Develop, delivery, connections, concepts

Page 12: Commented [NP49]

Nicole Pereira

8/08/2016 1:52:00 PM

I don't think we have a lot of redesign on... () Having said, we're very open to the fact that sometimes when you're on site, particular situations occur, so the builder can't do exactly what you want. So we're very open to having discussions with builders.

Delivery, redesign

Page 13: Commented [NP50]

Nicole Pereira

8/08/2016 1:53:00 PM

Usually, what we design is pretty close to what happens (...) The builder might say: Look, can I use this is a fixing mechanism? Sometimes, we say yes, sometimes we say no. (...) So, we normally design most things so we and the builders have an idea of what it's going on

Develop, delivery, redesign

Page 13: Commented [NP51]

Nicole Pereira

8/08/2016 1:55:00 PM

we do some projects where clients get amazing o the process themselves itcomes for very low budget, but you're often involved in hen th

Delivery, design and maker

Page 13: Commented [NP52]

Nicole Pereira

8/08/2016 1:57:00 PM

We do a lot of models, but mainly of the whole building. We very rarely do actual prototypes when we're using, you know, if I'm thinking of using a whole lot of panels, I won't go out and make a little model of how it would work, I just mentally work it out. () Once you've got your material, you know how you actually make that material fix and stay

Develop, delivery, connections, documentation

Page 14: Commented [NP53]

Nicole Pereira

8/08/2016 1:58:00 PM

You just constantly try to work out how you fix it. You're constantly thinking how to make this the simplest I can. Develop, delivery, connections, documentation

Page 14: Commented [NP54]

Nicole Pereira

8/08/2016 2:00:00 PM

It is about giving material a new life. And It is about time; it just takes time. And you've got to store it. Materiality, ROD, saved for later

Page 14: Commented [NP55] Nicole Pereira 8/08/2016 2:01:00 PM

People think recycled material cost a lot less but, in the end, they cost the same. Takes time. And they give the building history. It's not all shiny, brand new, but there's something about how it speaks with its past. And if it's done really well, it is really beautiful.

Discovery, define, materiality

Page 14: Commented [NP56] Nicole Pereira 8/08/2016 2:03:00 PM

But every building that gets demolished, they should make sure that all the material has to come out is stacked and so can be reused. But no. It is not going to happen for many years. Until new material start costing so much, that the labour involved in preparing becomes less... and that day will come, when half of the material will be gone by then.

Material availability, Discovery

Page 15: Commented [NP57] Nicole Pereira 8/08/2016 2:04:00 PM

Because a lot of the materials we are talking come from buildings from 50's, 60's and 70's, and those materials were really good materials. The materials used in the 90's, by the time they get ripped out, they are so dodgily made, they are not made to last anyhow, they will disintegrate.

Discovery, materiality, material avai

### C3. Coding 2: Phooey Architects

Page 2: Commented [NP1] Nicole Pereira 1/08/2016 4:38:00 PM

pulling the building apart and putting it back together in different way

discovery

Page 2: Commented [NP2] Nicole Pereira 1/08/2016 4:39:00 PM

I became connected to was the realization that whatever you design you will produce waste.

discovery

Page 2: Commented [NP3] Nicole Pereira 1/08/2016 4:39:00 PM

What do you do with that waste?

Define

Page 3: Commented [NP4] Nicole Pereira 1/08/2016 4:41:00 PM

We're likely to triple the amount of solid waste produced in the world by three nount by twenty-one times the a hundred

Discovery

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**Page 3: Commented [NP5]** **Nicole Pereira** **1/08/2016 4:41:00 PM**

all the stuff, all the nuts and bolts and screws and scenes and fittings that I've been collecting for the last twenty, thirty, forty years... that I've had just moving around from place to place. The reality is that I didn't need any of that stuff.

Material saved for later

**Page 3: Commented [NP6]** **Nicole Pereira** **1/08/2016 4:42:00 PM**

all of that stuff sticks together. You can work in an industrial kind of level or at a smaller scale. Materiality

**Page 4: Commented [NP7]** **Nicole Pereira** **1/08/2016 4:43:00 PM**

That greatest potential is actually for D.I.Y. sectors

Discovery

**Page 4: Commented [NP8]** **Nicole Pereira** **1/08/2016 4:44:00 PM**

before we learn how to speak, we learned how to work and make tools'. And some say that of takes the effort of why of going to war... working with tools sort

Designer and maker

**Page 6: Commented [NP9]** **Nicole Pereira** **1/08/2016 4:45:00 PM**

people grow and think in two different types of ways either is as bricoleur or as the engineer... someone who is systematized, but thinks of concepts that are beyond this world. And then there are the Bricoleur...the one that makes what's available and understands the constraints of what he's actually working with. Designer and maker

**Page 6: Commented [NP10]** **Nicole Pereira** **1/08/2016 4:46:00 PM**

But at the end of the day it is cost benefit analysis for whether to reuse something or not. It is not for its personal memory or attachment or whatever not it's just a recognition that a lot of these resources that we are removing or throwing away, whether is material or immaterial, can be potentially useful. Discovery, Define

**Page 6: Commented [NP11]** **Nicole Pereira** **1/08/2016 4:47:00 PM**

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it's important to recognize that we do have infrastructure or any industry that we're able to access a set up that whole bunch of stuff.

Discovery

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**Page 6: Commented [NP12]** **Nicole Pereira** **1/08/2016 4:48:00 PM**

we have these resources not only physically but also online.

Discovery

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**Page 7: Commented [NP13]** **Nicole Pereira** **1/08/2016 4:48:00 PM**

comes down to what you're looking for and why you're looking for

Discovery, Define

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**Page 7: Commented [NP14]** **Nicole Pereira** **1/08/2016 4:49:00 PM**

it's important to involve material but I don't think is a deciding factor in what you are guided by from your functional brief

Define

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**Page 7: Commented [NP15]** **Nicole Pereira** **1/08/2016 4:50:00 PM**

it is important to know what you have but it's also important what you need so you can tailor what you then you can specify rather than just use stuff that you need

Discovery, Define

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**Page 8: Commented [NP16]** **Nicole Pereira** **1/08/2016 4:50:00 PM**

I've just got organized and I have not catalogued

Material information

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**Page 8: Commented [NP17]** **Nicole Pereira** **1/08/2016 4:51:00 PM**

People who have collected things from everywhere, thinking exactly the same way, that it will be useful one day. Material saved for later

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**Page 9: Commented [NP18]** **Nicole Pereira** **1/08/2016 4:52:00 PM**

why it's valuable to have the demolishing yards and places that I can just go to, I also just go there and you know, I collect stuff harvesting, Discovery

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**Page 9: Commented [NP19]** **Nicole Pereira** **1/08/2016 4:52:00 PM**

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how they might change the role of the things that they have

Define

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**Page 9: Commented [NP20]** **Nicole Pereira** **1/08/2016 4:53:00 PM**

Everyone here is an architect

Working team

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**Page 9: Commented [NP21]** **Nicole Pereira** **1/08/2016 4:53:00 PM**

were all involved in all the projects. I'm involved from the design perspective at the front end, my wife makes it all work and has the team working

Working team

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**Page 10: Commented [NP22]** **Nicole Pereira** **1/08/2016 4:54:00 PM**

how we approach that what does that actually mean for us in terms of expanding the campaign of awareness that might, you know, we might call?

Discovery, ROD drivers

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**Page 10: Commented [NP23]** **Nicole Pereira** **1/08/2016 4:55:00 PM**

to be able to demonstrate so... here are all gates or the fences that we've pulled down from all of your houses and now we're going to make furniture out of it, and actually doing that 'how-to' session Develop and deliver

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**Page 10: Commented [NP24]** **Nicole Pereira** **2/08/2016 11:48:00 AM**

I think here in Australia, I could be wrong but, our residential sector... in terms of its econ Bunnings, the D.I.Y. marketplace. And then that's also the mass audience Australia DIY profile, Discovery

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**Page 11: Commented [NP25]** **Nicole Pereira** **2/08/2016 11:49:00 AM**

It is just a standard normal architectural process.

Office workflow, procedures. Discovery, define.

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**Page 11: Commented [NP26]** **Nicole Pereira** **2/08/2016 11:52:00 AM**

I decided to make a fire pit. And I decided that fire pit was going to be made out of the inside of a washing machine. And when I went to look for a washing machine, I couldn't find a washing machine from all the different people who either throw washing machines out or rework them because today, even though they're very beautiful, with the inner holes and the fire coming out of it. Reality is...it doesn't last very long, it's actually all plastic.

Define. Material information.

**Page 11: Commented [NP27]**                      **Nicole Pereira**                      **2/08/2016 11:54:00 AM**

That's depends on the knowing where to look, but also knowing what you want to do on that kind of scale. Obviously, there's different it's the same kind of processes I would go through. Thinking about reusing or finding things to reuse and finding things to reuse just because it's available.

Discovery

**Page 12: Commented [NP28]**                      **Nicole Pereira**                      **2/08/2016 11:55:00 AM**

we need to document existing conditions.                      is something small or something larger, that just needs to be documented                      Wherever documented                      largbe

Material information

**Page 12: Commented [NP29]**                      **Nicole Pereira**                      **2/08/2016 11:57:00 AM**

we try not to keep stuff. We try to just use it and get rid of it but the stuff that we use often on projects and building sites. We don't know what we have until we pull things apart...all the leftovers that we have, we just need to account for it

Discovery, define, save for later

**Page 12: Commented [NP30]**                      **Nicole Pereira**                      **2/08/2016 11:58:00 AM**

then we need them (the builder) to know approximately what's happening with all of the waste and how it's going to be put together. The whole strategy is prepare for them.

Develop, deliver

**Page 12: Commented [NP31]**                      **Nicole Pereira**                      **2/08/2016 11:59:00 AM**

what we're doing is craft based. It is not                      so not everybody can do it. Is it                      for us to be able to that easy, document what we have                      important

Develop, documentation

**Page 12: Commented [NP32]**                      **Nicole Pereira**                      **2/08/2016 12:00:00 PM**

we document everything we need to know

Develop, documentation

**Page 12: Commented [NP33]**                      **Nicole Pereira**                      **2/08/2016 12:01:00 PM**

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this documentation is just as inventory  
Material Information, documentation

**Page 12: Commented [NP34]** **Nicole Pereira** **2/08/2016 12:01:00 PM**

inventory of stuff that we have and how will we catalogue to able to be retained on site or relocated and measured and quantified or you need to understand what risks involved in reusing it if it's reusable at all Material information and discovery

**Page 13: Commented [NP35]** **Nicole Pereira** **2/08/2016 12:02:00 PM**

We use BIM (...) and we do that so that we can get it in three dimensions and make families of stuff  
Develop, digital tools

**Page 14: Commented [NP36]** **Nicole Pereira** **2/08/2016 12:05:00 PM**

We try to do things as easily as standard as possible, what is familiar in terms of skilled knowledge. That's basically from where we start. Different builders can do different things  
Develop and delivery

**Page 14: Commented [NP37]** **Nicole Pereira** **2/08/2016 12:06:00 PM**

We try to do things as easily as standard : what is familiar in terms of skilledwledge. That's possible, from where we start. Differeknof erent things basically  
builders can do dif  
Define, develop, delivery, redesign

**Page 14: Commented [NP38]** **Nicole Pereira** **1/08/2016 2:59:00 PM**

We might demolish the building, but if we do demolish it, can we pull it apart? If we can pull it apart, how can we pull it apart? If we do then, where do we actually store that? And how do we actually patch that, if it needs to be patched to be able to be reused and then, can it be reused again in the same way or differently?  
Discovery, define

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reusing wasted resources in another productive way Discovery, Upcycle definition

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How important is it to actually to be  
working with valid

the materials or to be one step awayn that? I think both  
fro are

Discovery, Materiality

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**Nicole Pereira**

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if I take it from a collage perspective there's a point of difference as a point of similarity in terms of the conversation, that all they seem to go together. That's a starting point, as opposed to feeling the material and knowing what it can do. But the question is how different material operate? Discovery, materiality