A Decentralized Autonomous Organization framework to facilitate Architectural Design Evaluation

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Master Thesis

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Abstract

Design evaluation is a crucial aspect of architects' education and professional practice, yet it has often been overlooked and undervalued within professional working environments. This research aims to address this problem by exploring the potential of applying blockchain technologies and decentralized autonomous organizations (DAOs) to facilitate architectural design evaluation among architects. The research presents a theoretical DAO framework developed through insights from previous research and interviews with architects, comprising a membership system and an evaluation system with extensive design evaluation criteria. The membership system ensures the quality of evaluation feedback by only granting qualified architects to join the DAO, while the evaluation system provides an extensive design evaluation with comprehensive evaluation criteria. Through simulation tests and expert reviews, the framework's effectiveness is validated, generating optimism among architects and promising expectations. The findings highlight the potential of DAOs to promote efficiency, transparency, and innovation in architectural design evaluation or other industries. At the end of the research, several directions of future research are suggested regarding the extension of existing DAO framework with broader functionalities.

Keywords: architectural design evaluation, decentralized autonomous organizations, blockchain technologies, membership system, evaluation system, transparency.

Preface

At the time I was starting this research in 2022, I was deeply attracted by the idea of Decentralized Autonomous Organization where a group of people can gather for a shared mission and build an kind of organization they wish to stay and make it better while feeling passionate about it, no matter where and who they are, just like a normal business. Because the technology of blockchain, and the decentralization culture it represents allows this kind of business to happen and thrive in a way that people have never imagined, I believe that is something that people who are continuously contributing to this industry wish to see and the future they are trying to shape. After that, I happened to read the paper ' Collective Digital Factories for Buildings: Stigmergic Collaboration Through Cryptoeconomics' by Dounas, Lombardi (2022) where he and his research inspired me through his idea of applying DAO-like concepts into architecture valuation to improve the efficiency of collaboration between architects. That is when the idea of this research was actually formed. Over the past months, I have been trying to refine the problems exist in architectural design evaluation and conceiving the DAO model that is able to solve those problems and how could it adapt the situations architects are experiencing. Fortunately, it came to a way that is both practical and insightful as you could read them over the results of the research. During this entire process, there are plenty of people I feel deeply gratitude with by helping me finish this research. First, I would like to offer my gratitude to Professor Ekaterina Petrova, who has always been supporting my idea and keeping me on track over the entire research process and encourage me to purse my ideas and ambitious freely. Then, I would like to thank my second supervisor, Stefan Driessen, with his insightful advice and creative mindset which illuminated the direction for my research, so I am able to complete this research ahead of schedule. Additionally, I would like to thank Pieter Pauwels who has always been supportive and helpful in my research and previous courses, providing diligent support and advice, and all of interviewed architects and their insights which have been extremely helpful to research. Without them, it would take me much longer to finish this research. Lastly but not with the least gratitude, I would like to thank my parents and other families who have always been encouraging and supportive to my study and pursuit even we are thousands meters away from each other, without them, I could never become who I am today. In conclusion, it is my sincere hope that every individual who takes the time to read this paper finds it to be both inspirational and beneficial to their own research. May the insights shared within these pages serve as a catalyst for new ideas, encouraging exploration and innovation in built environment. The field of research is vast and continuously evolving, and it is my greatest ambition that this contribution will in some way aid in your exploration and understanding.

Zhijiang Chen
June 2023

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Management Summary

Design evaluation has been a controversial subject in the architecture industry for decades due to its complex nature of involving multiple parties in a project and often being determined by subjectivity from stakeholders [21]. Yet, design evaluation is a rather important aspect for architects, especially in both their career and education, as it offers opportunities to critically reflect on their design choices and understand the strengths and weaknesses inherent in their designs. Moreover, it highlights areas for improvement and gaps in architects' existing knowledge, which further fosters a culture of continuous learning and skills improvement. Design evaluation is a dynamic interaction process for both sides of evaluation, and it often nurtures mutual understanding, potential creativity, and innovation in this area [25]. During interviews with several architects, it was revealed that even after graduation, some architects still tend to seek external evaluation or consultation for their designs for potential improvements.

However, recently, the importance of design evaluation has been dramatically undervalued in architecture projects. Stakeholders tend to put more focus on profit, budget, and other financial factors while missing the importance of sustainability, circularity, and other important factors that are supposed to be considered during architectural design [40]. On the other hand, a shift in trend is noticeable in Europe where these important factors are becoming standards in architectural design and construction. Evaluations among architects generally end up being a 'battle of tastes.' Therefore, architects are increasingly demanding a comprehensive evaluation system to reduce the impact of subjectivity and a platform for design evaluation and feedback, according to interviews conducted for this research.

Decentralized Autonomous Organizations (DAOs), as a new form of organizational model based on blockchain technology, have been gathering significant attention. In recent years, DAOs have been applied to various sectors such as finance, charity, and art, with their defining characteristics of transparency, decentralization, and efficiency acting as catalysts for this trend [3]. These important features make DAOs an ideal prospect for their application within the field of architectural design evaluation. Therefore, this research embarks on exploring the possibilities of DAOs in facilitating the evaluation of architectural design. The advent of a DAO within this context could pioneer an evaluation platform that is comprehensive, transparent, secure, and underpinned by democratic principles [78]. Furthermore, DAOs can facilitate an environment and culture for networking, collaborative problem-solving, and knowledge sharing, offering architects continuous opportunities for refining their designs based on community feedback. The democratic structure and transparency nature of DAOs ensure evaluations incorporate a wide range of perspectives, thereby enriching the overall evaluation process. To this end, this research aims to conceptualize a DAO model with two key components: an exclusive membership system to ensure high-quality feedback and an extensive evaluation mechanism to promote objective evaluations.

This research follows the methodology of Design Science Research (DSR), leveraging the design cycle model proposed by Wieringa [74] to develop a Decentralized Autonomous Organization (DAO) framework for architectural design evaluation. The first phase, problem investigation, sets the stage for the research where foundational knowledge in blockchain and DAO is acquired through an exhaustive literature review, creating the theoretical underpinning of the research. In parallel, interviews with architects reveal the practical challenges they are facing in design evaluation and gain insights about their expectations for a comprehensive evaluation model.

In the next phase, artifact design and development, the research draws insights from previous DAO models to form the basic framework of the proposed DAO. Specific components, such as the membership system and the evaluation model, are designed to meet the expectations highlighted by the architects.

These components are then integrated to form a cohesive and effective DAO framework for architectural design evaluation. In the final

phase, artifact validation, the developed DAO framework undergoes a simulation test to evaluate the functionalities of the smart contract underpinning the membership system. Further, expert reviews from experienced architects evaluate the practicality and efficacy of the design evaluation model. This methodology allows for the systematic development and thorough testing of a DAO framework for architectural design evaluation, which is geared towards addressing the real-world challenges faced by architects.

Consequently, several key findings are identified from the results of the research. Most importantly, there is substantial potential for DAOs to be implemented in the architectural design field, as the decentralization feature of DAOs can help minimize the influence of subjectivity in the design evaluation process, although it's important to acknowledge that complete elimination of subjectivity is challenging. Nonetheless, a more comprehensive evaluation model can considerably reduce its impact.

Based on these findings, this research recommends further exploration of DAO models with more comprehensive functionalities that can suitably accommodate the complexities of architectural design evaluations like incentives and voting governance that are generally included in the DAO framework. This research suggests that the DAO, with its transformative organizational model, warrants exploration in various directions to uncover its full potential in addressing multifaceted challenges in diverse fields.

Despite these encouraging findings and recommendations, the study acknowledges certain limitations. First, the scope of this research was limited to architectural design evaluation, so the applicability of findings might not be entirely transferable to other contexts or fields. Second, the evaluation criteria used in this study were developed based on a literature review and stakeholder interviews, meaning they may not encompass all possible aspects of design evaluation in different contexts or according to individual perspectives. Finally, the study faced the challenge of validating the practice of DAOs, given that DAOs themselves represent a relatively new and rapidly evolving field, and established methods for their evaluation and validation are not yet comprehensive. Future research in this area would undoubtedly contribute significantly to the growing body of knowledge surrounding DAOs and their applicability across different domains.

Chapter 1

Introduction

1.1 Background

For architects, design evaluation plays a significant role in their education by offering opportunities to critically reflect their design choices, understanding the strengths and weaknesses inherent in their design. Furthermore, it illuminates areas for improvement and highlights gaps in existing knowledge, fostering a culture of continuous learning and skill enhancement. During an evaluation process, the dynamic interaction between architects and evaluators nurtures a profound understanding of architectural design, fostering the potential for creativity, innovation, and refined design understandings [25].

In recent years, the evaluation of architectural designs is no longer confined to a single perspective but spans across multiple domains, aiming to elevate the design's overall quality. This holistic approach encompasses various subjects including sustainability, circularity of design, effective solutions to design challenges, creativity, and conformity to established standards, among others [14]. This expansive coverage from design evaluation not only facilitates comprehensive reviews but also promotes an integrative thinking process, enabling architects to consider various factors in the early stage of their design. The evaluation model and teaching approach ensures architects receive more nuanced and detailed feedback, and the design itself becomes a product of various intersecting considerations, reflecting a more balanced and well-thought-out concept [25].

In a professional environment, architectural design evaluations have become increasingly dominated by financial gains and cost considerations, overlooking other crucial aspects. These aspects, including sustainability, circularity, human well-being, and aesthetics [14], often take a backseat in the evaluation process, limiting the comprehensive and objective evaluation of architectural designs. Currently, there is no public architects based associations that focus on architectural design evaluation, therefore, architects often rely solely on feedback from colleagues or supervisors, which is a rather restricted circle, that may not always provide comprehensive, objective evaluations [21], which caused limited opportunities for extensive feedback thus often demotivate the evaluation process.

Interviews conducted during this research, with a number of practicing architects, also revealed this concern, there is a significant demand among architects for a more comprehensive and objective evaluation system that can accommodate a diverse range of design criteria. Such a system, they believe, would not only facilitate a more objective valuation of their designs but also significantly reduce inherent bias during an architectural design evaluation. However, such a comprehensive evaluation system appears to be conspicuously absent from their professional workflow. This deficiency is not a new issue but a persistent gap that architects have grappled with since their academic training.

Addressing the identified shortcomings in architectural design evaluations, this research integrates a novel, decentralization-focused organizational paradigm, DAO, powered by blockchain technology. This model serves as a dynamic and transparent platform that facilitates exhaustive architectural design evaluations while promoting knowledge exchange, networking, and equality in decision making. The

DAO's unique organizational structure, underscored by decentralization and transparency, empowers architects to participate in interactive feedback sessions and discussions, enabling the iterative refinement of their designs. The lack of a central authority ensures that all voices are equitably considered, leading to comprehensive evaluations that incorporate a diverse array of perspectives. Additionally, the transparent nature of DAOs facilitates clear visibility of evaluation criteria and decision-making processes, effectively addressing potential trust issues. Ultimately, the DAO's integration in architectural design evaluations supports architects in pushing the boundaries of their designs, thereby enhancing their quality, creativity, and sustainability [78].

1.2 Problem definition

The previous section established the foundation for problem identification of this research. First, the desire from architects for a more comprehensive and extensive evaluation system to help them in both personal growth and career success, which the current evaluation frameworks fail to cater to. Secondly, to address this lack of objectivity issue, this research aims to incorporate a Decentralized Autonomous Organization (DAO) as a potential solution which provides a platform for architects to evaluate each other's design. However, the application of DAOs in the field of architectural design evaluation presents its own set of challenges due to the lack of a structured implementation framework. Thus, these combined insights have raised two key research gaps that this research aims to address.

The first gap lies in the absence of a comprehensive evaluation system for architectural design. Traditional evaluation methods are often constrained by a limited perspective, focusing primarily on individual elements such as cost-effectiveness or functional utility. In contrast, architecture as a discipline requires a broadened perspective that accommodates various parameters, including sustainability, circularity, aesthetic quality, cultural context, among others. Many interviewed architects have expressed a need for an evaluation system that caters to this variety, fostering the development of balanced and innovative design solutions. Unfortunately, such a comprehensive evaluation system, which effectively synthesizes these diverse factors, remains absent in professional practices. This deficiency hinders the growth of architects and constrains the architects' capacity to generate, refine, and improve their creative output.

The second problem arises in the absence of architect-based associations or organizations explicitly focusing on design evaluation. This gap leaves architects often reliant on less structured, more casual feedback methods that may not provide the comprehensive, objective evaluations needed to foster significant growth and improvement [21]. Furthermore, the traditional centralized nature of these organizations often subjects them to criticism due to perceived lack of transparency and efficiency. Such structures can inadvertently promote bias or restrict the diversity of evaluative perspectives, thereby limiting the value and comprehensiveness of feedback provided [40]. These shortcomings highlight the importance for a decentralized, transparent, and efficient solution. DAOs, with their capacity to democratize decision-making and create extensive, open networks, present a potentially transformative solution to these long-standing issues mentioned above [78].

Addressing these identified gaps is crucial as it can enable significant advancements in architectural design evaluations and foster the adoption of innovative practices such as DAOs within the architectural domain. The proposed DAO framework provides a solution which includes a platform – a membership system powered by smart contracts – ensuring the quality of designs that architects receive for evaluation. This system also includes a comprehensive design evaluation system, encompassing a wide range of design evaluation criteria and offering a solution to the demand from architects for a platform specifically designed for design evaluation and addresses the lack of objectivity and prevalence of subjectivity in existing design evaluation systems by providing a comprehensive and more objective evaluation approach.

1.3 Research questions

Following the problem statement, the main research question that needs to be answered in this research is defined as :

How to design a Decentralized Autonomous Organization (DAO) framework that provides a comprehensive architectural design evaluation system to enable more objective design evaluations?

The proposed research question explores the methodology to design a DAO framework that explicitly caters to design evaluation among architects that would provide both platforms for architects to interact with each other and comprehensive evaluation system leading to more objective design evaluation results and feedback. By emphasizing the terms 'comprehensive' and 'objective', the goal is to capture all aspects relevant to architectural design, such as sustainability, aesthetic value, and cultural context, while minimizing subjective biases for fair evaluation results. By incorporating the principles of DAOs - decentralization, transparency, and autonomy, the proposed DAO framework leverages collective decision-making power to address identified challenges in the current architectural design evaluation practices. And this fundamental research question paves the way for further, more specific investigations which come as more sub-research questions, serving as a guiding structure that navigates the journey of this research.

To answer the main research question, the following sub-research questions are defined:

1. Why is an extensive architectural design evaluation required and necessary for architects?

This question aims to investigate the importance of comprehensive architectural design evaluation for architects, highlighting its role in architects' personal growth, skill development, and potential innovation in their designs.

2. Why should a DAO be a solution rather than a traditional organization?

This question explores the potential advantages of implementing a DAO in place of a traditional organization, focusing on aspects such as decentralization, transparency, trustworthy system, and the potential for networking and feedback.

3. What features and characteristics should be expected by architects from the DAO?

This question seeks to understand what architects would expect from a DAO, for instance, features that support their design evaluation needs, facilitate interaction, and promote a dynamic evaluation environment.

4. How would the DAO provide quality design evaluation?

This question investigates the ability of the DAO to ensure effective and objective architectural evaluations. It questions the DAO's capacity to maintain quality and standards, and whether the decentralized nature of the DAO could uphold the integrity of evaluations.

5. Can the DAO provide comprehensive architectural design evaluation?

This question validates the comprehensiveness of the architectural design evaluation provided by the DAO. It aims to understand if the DAO can cover all the evaluation criteria desired by architects, such as sustainability, circularity, cultural values, and aesthetics, alongside the usual cost and profit factors.

1.4 Scientific relevance

The scientific relevance of this study lies in its innovative exploration of applying decentralized blockchain technologies, specifically DAOs, to the architecture domain. This research contributes to the developing body of knowledge at the intersection of blockchain technology and architectural practice. The DAO framework developed through this study could introduce a novel approach to design evaluation, fostering more transparent, democratic, and comprehensive evaluation approach for arcitectural designs. Furthermore, the insights gleaned from this research could stimulate further academic discussion and empirical investigation into the broader applications of blockchain technologies in the built environment and beyond. Thus, this study not only addresses a specific gap within architectural discourse but also enriches

our broader understanding of how emerging technologies can reshape traditional practices in various disciplines.

1.5 Practical relevance

This research addresses the prevailing gap in the architectural domain regarding the demand for a more comprehensive and objective architectural design evaluation system, which is currently unfulfilled. By incorporating a DAO framework into the evaluation process, the research provides architects with an innovative platform which covers a diverse range of evaluation criteria and promotes increased transparency, accountability, and collaboration. Additionally, this research reveals the potential of DAO in the architectural field, outlining its implementation process and intrinsic advantages. This understanding empowers architects and related professionals in the built environment industry to integrate blockchain technologies into their regular workflows.

In terms of practical application, the unique attributes of DAO, characterized by its decentralized and democratic operations, ensure participation from credible architects only. This credibility is determined through a structured membership system within the DAO, where architects are assessed based on their professional credentials, expertise, and experience. This rigorous assessment of members ensures that only competent and experienced professionals contribute to the evaluation process, thereby enhancing its credibility. In terms of ensuring objectivity, the design evaluation process employs structured evaluation criteria that consider a diverse range of design factors. This structured approach aids in reducing the influence of personal biases, thereby enhancing the objectivity of the evaluation process. Furthermore, the decentralized nature of the DAO allows for a diversity of perspectives in the evaluation, further bolstering its objectivity. Therefore, this optimized structure guarantees the effectiveness of the evaluation, assures its quality and objectivity, and attributes this research with profound practical relevance.

1.6 Reading guide

This master thesis is structured in a way that makes it easier for readers to follow and understand. Therefore, the first two chapters (introduction and methodology) will discuss the outline and overview of the research and how it will be carried out along the way. After that, a comprehensive literature review (Chapter 3 & 4) will be conducted studying concepts architectural design, blockchain and decentralized autonomous organizations (DAO) comprehensively. Then, a number of interviews will be conducted and discussed (Chapter 5) for data collection purposes to collect more relevant information about the context of architectural design evaluation and help the researcher to identify the main problems, stakeholders and objectives of the research. Next, as this research follows the structure of Design Science Research (DSR), Chapter 6 will discuss artifact design and artifact development which mainly is about how the framework of DAO is designed and developed based on the data collected from previous phases. Chapter 7 will discuss the process of artifact validation, where the assumption made and artifact developed will be validated against several validation approaches. In the final chapter (Chapter 8), all answers to research questions and sub-research questions will be presented to provide a comprehensive research overview and recommendations to future relevant research.

Chapter 2

Research Methodology

This chapter will be discussing the research methodology employed in this research to develop the Decentralized Autonomous Organization (DAO) framework for architectural design evaluation. At the moment, there is a lack of knowledge on how to improve the evaluation situations between architects, therefore, the main purpose of this research is to create a practical framework that facilitates an effective and objective architectural design evaluation process between architects using a DAO approach, while ensuring the quality of design evaluation results. To achieve that purpose, the Design Science Research (DSR) method is employed, which focuses on creating and evaluating artifacts that address complex problems and contribute to the enhancement of human and organizational capabilities, the detailed implementation phases will be explained in the following sections. After that, the research process, based on the DSR methodology, consists of 3 main phases, namely problem investigation including literature study and interviews with architects, artifact(the DAO framework) design and development and artifact validation. In order to collect data about the status quo of the architectural design evaluation process, interviews with architects will be conducted and results will be organized and regarded as primary data for the research after the theoretical background has been established through literature reviews regarding architectural design evaluation. The DAO framework will be build by developing and integrating essential components such as, smart contract for membership system and design evaluation systems, drawing on the insights and requirements identified from the problem investigation phase. Finally, the final phase entails testing and evaluating the developed DAO framework and smart contracts, assessing their effectiveness in addressing the identified problems in traditional architectural organizations. Through this comprehensive approach, the research aims to answer the defined research questions by developing a practical and objective framework for architectural design evaluation.

2.1 Design Science Research

DSR methodology is a well-established approach within the Information Systems (IS) field and other disciplines that focuses on addressing complex problems by creating and evaluating innovative artifacts such as models, methods, or systems. As DSR emphasises the creation and evaluation of artifacts that contribute to the enhancement of human and organizational capabilities, research that uses DSR as the primary research methodology will generally develop a framework, model, or artifact that addresses the research questions at hand. DSR expects to demonstrate the practical utility and effectiveness of these artifacts in solving real-world problems by rigorously evaluating them [34]. In the context of this study, DSR methodology will be used as a guide to create a DAO framework for architects in order to improve the effectiveness and objectivity of the architectural design evaluation process. DSR follows a structured, iterative process model known as the DSR cycle, which includes several steps such as problem identification, objectives definition, design and development, demonstration, evaluation, and communication. The research cycle model guides researchers through a structured and iterative approach that allows for the development of artifacts through a user-centered design process while considering the requirements and constraints of a given context. It also assists researchers in refining their artifacts by incorporating feedback, learning from previous iterations, and ensuring their effectiveness in addressing real-world problems

[74, 55].In Wieringa's [74] research, two DSR cycles are introduced: design cycle and engineering cycle. While the design cycle focuses on conceptualization and development of the research artifact, the engineering cycle focuses on practical implementation and evaluation of the artifact in the target environment. The design cycle covers problem analysis, artifact design, and artifact validation, while the engineering cycle adds artifact implementation and implementation evaluation on top of the design cycle. According to Wieringa [74], design cycle belongs to a large cycle, engineering cycle (Figure 1) which covers problem investigation, treatment design, treatment validation, treatment implementation, implementation evaluation. Given that this is an academic study, the primary emphasis is on the theoretical and conceptual development of the suggested framework, with the goal of contributing to the existing body of knowledge in the subject, rather than practical application, which is outside the scope of this study. As a result, just the design cycle and a portion of the engineering cycle will be used in this study.

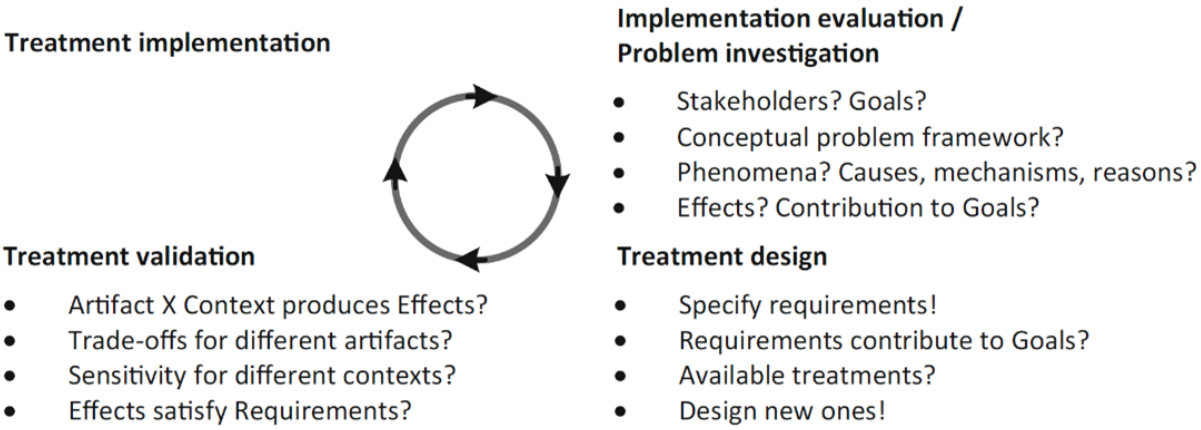


Figure 1: The engineering cycle (Wieringa, 2014)

The design cycle, as previously indicated, includes problem research, artifact design, and artifact validation. A smart contract will be develoed as templates and blueprints for future related study in the context of this research to improve the construction of DAOs. Although smart contract development is generally associated with the engineering cycle, this research integrates it into the design cycle, specifically within the artifact development stage, to promote a more thorough and unified approach. As a result, in order to answer the research questions, the entire research will be separated into three phases following the suggested Design Science Research cycle, as problem investigation, artifact design and development, and artifact validation, which will be discussed below (Figure 2).

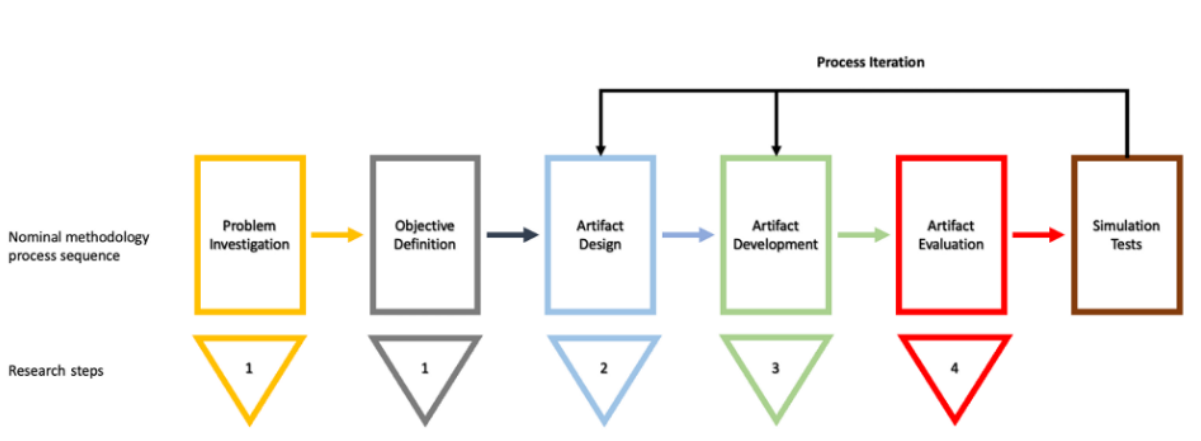


Figure 2: Design Science Research Process Model

2.2 Phase 1: Problem investigation

The first phase of DSR cycle being applied to this research is problem investigation(Figure 1) which includes literature study for theoretical foundation of the research, and interviewing with architects for deeper insights towards the research subjects. Over this phase, three of the sub-research questions will be answered: 1. Why is an extensive architectural design evaluation required and necessary for architects? 2. Why should a decentralized organization be a solution rather than a traditional organization? 3. What features and characteristics should be expected by architects from the DAO? The purpose of this phase is to identify and understand the research problems, stakeholders, objectives and contexts surrounding this research. This phase plays an important role in the whole research as it provides a solid foundation for the subsequent artifact design and development phase. To effectively conduct the problem investigation phase, a combination of literature study and interviews will be used for data collection purpose (Figure 3).

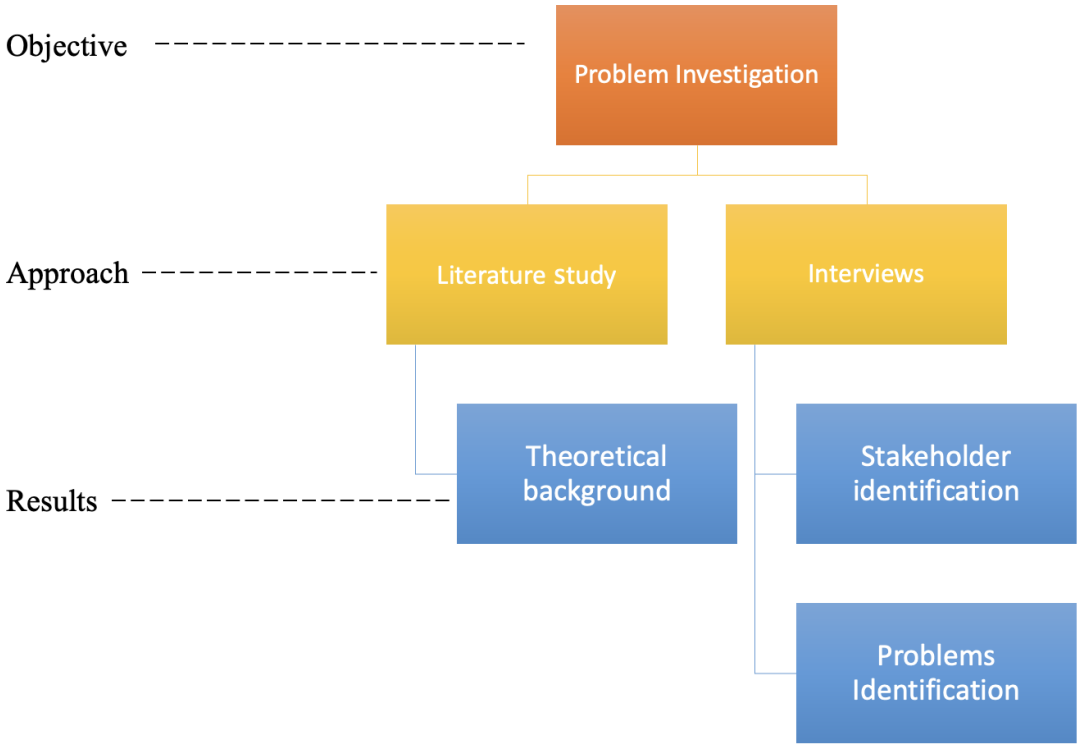


Figure 3: Problem investigation model

2.2.1 Literature study

A comprehensive literature review will be carried out initially, aimed at assessing and synthesizing the available knowledge, theories, and empirical findings related to the architectural design evaluation process, blockchain technology, and Decentralized Autonomous Organizations (DAOs). This phase is critical in comprehending the current status of research problems, spotting existing challenges, recognizing knowledge gaps, and identifying potential avenues for improvement.

The first part of the literature review will delve into the architectural design evaluation in the architectural industry. It will provide an overview of design evaluation and explore various forms of evaluation employed in this field. Importantly, it will bring to light the current problems that are relevant architectural design evaluation, thus setting the stage for the rest of the research.

The next part of the literature study will explore the backbone of DAOs—blockchain technology. It will initiate a comprehensive understanding of blockchain basics before highlighting the unique characteristics of the technology. This section will also probe into the core technologies that power blockchain and delve into the benefits that blockchain brings to the table, thus offering insight into why it is foundational for DAOs.

The final phrase of the literature review will focus on Decentralized Autonomous Organizations themselves. This part of the review will start by defining what DAOs are before examining their functionalities and distinguishing characteristics. Finally, it will also address the challenges and limitations of DAOs, offering a balanced view of this relatively new technology and its applicability in various scenarios.

In sum, the literature review will provide a comprehensive understanding of architectural design evaluation, blockchain technology, and DAOs, setting a solid foundation for the rest of the research.

2.2.2 Interviews with architects

In addition to the literature review and given the limited available literature discussing architectural design evaluation phase in a professional environment, conducting interviews with experienced architects becomes necessary to gain deeper insights into the practical aspects of the problem domain. These interviews will help identify the practical challenges, needs, and expectations of stakeholders when implementing DAOs in the architectural design evaluation process. Moreover, the interviews will provide valuable information that might not be covered in the existing literature, thus ensuring that the research addresses the real-world needs and concerns of stakeholders. The interview questions and logs can be found in the appendix(A-F). The interviews will be designed to gather information with the following purposes:

1. To identify the problems and difficulties from architects when it comes to architectural design evaluation.
2. To explore what the expected design evaluation approach for architects should look like.
3. To explore the potential need to a DAO from architects to realize the objective value of their design.
4. To understand the incentives that could encourage architects to participate in such a system
5. To gather insights and opinions from architects about the benefits, drawbacks, and challenges of implementing a DAO for architectural evaluation

By conducting interviews with professionals in relevant fields, the research will be able to develop a more comprehensive understanding of the problem domain and the context surrounding the architectural design evaluation process and the establishment of DAOs. The insights gained from the interviews will complement the findings from the literature study and set the stage for the subsequent artifact design and development phase, where a framework for DAOs for architects will be conceptualized and developed to address the identified problems and objectives.

2.3 Phase 2: Design and development

The design and development of the artifact, representing the second phase of the refined Design Science Research (DSR) cycle, will fundamentally rely on findings gathered from the initial problem investigation phase (as depicted in Figure 4). This figure elucidates five key stages integral to the process of artifact design and development. Initially, the conceptualization phase involves formulating a broad, yet comprehensive, understanding of the proposed solution, establishing its underlying principles based on research findings. Following this, the design phase embarks on structuring the artifact, taking into account the specific needs identified during the investigation. Subsequently, during the development phase, these design blueprints come to life, transforming into a tangible DAO framework. This development

is followed by a rigorous validation phase, where the effectiveness and efficiency of the created DAO framework are assessed against set criteria. The cycle concludes with an iterative phase that embraces a continuous improvement mindset, integrating feedback from the validation phase and making necessary adjustments to refine the artifact further. This integrative process ensures a comprehensive, user-oriented solution addressing the identified problems within architectural design evaluation. In the following subsections, the project's detailed progression will be broken down, focusing on the planning and execution of each phase in the design and development of the artifact. This will offer a thorough understanding of how the insights gathered during the problem investigation phase influence the overall framework of the Decentralized Autonomous Organization (DAO) tailored for architectural design evaluation.

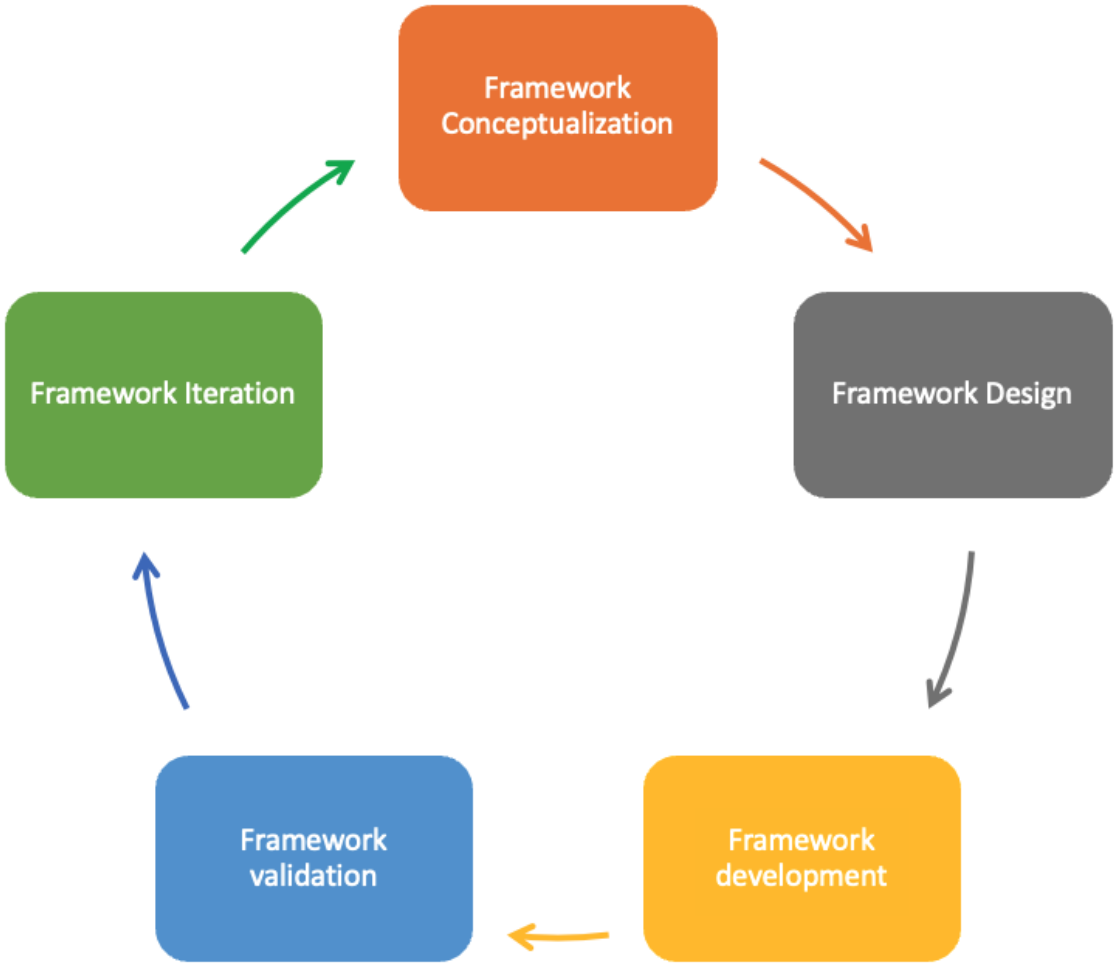


Figure 4: Artifact design and development model

2.3.1 Framework conceptualization

The conceptualization phase focuses on synthesizing the insights and problems gathered from the literature review and interviews to develop a comprehensive understanding of the necessary components, relationships, and mechanisms for the proposed DAO framework. This involves identifying the key elements essential for the effective functioning of the framework, such as:

1. Stakeholders: Determining the individuals and entities involved in the architectural design evalu-

ation process, taking into account their diverse perspectives and expertise.

2. Roles and Responsibilities: Defining the specific roles and responsibilities of stakeholders within the DAO, ensuring a clear division of labor and accountability.

3. Decision-making and Interactions: Examining the types of decisions and interactions that occur during the evaluation process, and incorporating mechanisms that facilitate effective collaboration and communication among the participants.

4. Blockchain Technology and Smart Contracts: Selecting the appropriate underlying blockchain technology and designing smart contracts that enable the establishment, operation, and governance of the DAO.

To provide a comprehensive and easily understandable representation of these components and their interrelationships, a conceptual model will be designed and developed. This high-level overview of the DAO framework will serve as a visual guide for architects and other stakeholders to grasp the fundamental aspects of the proposed solution, facilitating its implementation and adoption in the architectural design evaluation process.

2.3.2 Artifact design and development

Following the conceptualization of the framework(artifact), the next phase involves the development of the artifact itself. This phase essentially translates the conceptual model into a comprehensive, well-structured, and operational DAO framework. The key aspects of this development phase include:

1. Defining processes and workflows: The first step in this process involves defining the specific workflows and procedures that take place within the DAO. These workflows are centered around facilitating architectural design evaluation and encouraging knowledge sharing among participants. To ensure a smooth and user-friendly experience for all stakeholders involved, these processes are designed to be streamlined and efficient.

2. Establishing the Tech Stack: The framework of the DAO requires specific technologies. Solidity is used for writing smart contracts due to its compatibility with the Ethereum Virtual Machine (EVM), where these contracts are deployed and executed. To manage the compiling, testing, deploying, and verifying the smart contracts, Hardhat, a development environment for Ethereum, is employed. In order to store membership data in a decentralized manner, the InterPlanetary File System (IPFS), a protocol designed to create a permanent and decentralized method of storing and sharing files, is utilized. Finally, Git, a distributed version control system, is used for tracking changes in the smart contract source code during software development.

3. Developing smart contract templates: Another essential step in artifact development is creating smart contract templates that govern various DAO functions such as membership management, design evaluation management, and so forth. These templates are developed using Solidity and managed with Hardhat, ensuring they are aligned with the standards of the Ethereum blockchain.

4. Designing an extensive evaluation system: The final key component is the design of an extensive evaluation system. This system encompasses a wide variety of evaluation criteria obtained from both literature and the input of practicing architects. By integrating this extensive evaluation system within the DAO framework, it provides a comprehensive and objective architectural design evaluation platform.

Through the development of these components, the artifact development phase actualizes the conceptualized DAO framework, thereby creating a comprehensive, objective, and decentralized platform for architectural design evaluation.

Throughout the artifact development process, the research will emphasize the importance of aligning the proposed framework with the real-world needs and requirements identified during the problem investigation phase. In addition, the framework will be grounded in the existing knowledge and theories gained

from the literature review, ensuring its relevance, feasibility, and effectiveness in addressing the challenges and providing opportunities in architectural design evaluation.

2.3.3 Artifact validation

The validation phase of the artifact consists of two key components: a simulation test focusing on the smart contract's functionality, and an expert review targeted at assessing the overall framework with a particular emphasis on the evaluation system.

The simulation test was executed to evaluate the smart contract within the DAO framework. In this test, a smart contract was deployed on the Ethereum testnet, which replicates the Ethereum network's conditions but without real value associated with the Ether cryptocurrency. This test environment allows for a comprehensive assessment of the smart contract's functionality without the risk of losing actual resources. To validate the functionalities, simulated participants were created to interact with the smart contract. These participants initiated a variety of actions and transactions that a real participant would, such as joining the DAO, submitting designs for evaluation, voting on designs, and so forth. By conducting these simulations, we were able to observe and evaluate the behavior of the smart contract under different scenarios, thereby validating the functionality and practicality of the smart contract, and by extension, the entire DAO framework.

The expert review component of the validation phase was designed to gather insights from professional architects regarding the developed evaluation system within the DAO framework. Specifically, two experienced architects were interviewed and asked to provide their opinions on the design evaluation system. The basis for the feedback revolved around a detailed explanation and demonstration of the system, after which the architects were asked to reflect on its relevance, usability, comprehensiveness, and potential areas for improvement. The aim was to understand how well the developed framework addresses the existing challenges architects face in design evaluation. The feedback from the architects, being the potential end users of the system, offers valuable insights into the strengths and weaknesses of the proposed DAO framework. Their expertise helped identify potential areas of improvement and affirm the aspects that work well, thus ensuring the validation of the evaluation system from the perspective of its intended users.

This validation phase ensures that the resulting artifact is both theoretically coherent and practically beneficial in enhancing the architectural design evaluation process. The findings derived from the validation process will inform the framework's finalization and contribute to the overall conclusions and contributions of the research.

2.3.4 Summary

In conclusion, the research methodology chapter has outlined a systematic approach to investigating the problem and developing a DAO framework for architectural design evaluation. And this chapter has provided a clear overview of the research design, data collection and analysis approach to ensure the validity and reliability of the research findings. Furthermore, various phases of the research process have been explained including problem investigation, conceptualization/artifact design, iterative refinement, and validation and evaluation, highlighting the importance of each step in achieving the research objectives.

As the study progresses to the literature review chapter, the comprehensive understanding gained from the methodology will serve as a foundation for exploring relevant theories, concepts, and existing knowledge in the fields of architecture, DAOs, and blockchain technology. This exploration will provide valuable insights into the current state of design evaluation in the architectural industry, as well as the potential applications and benefits of the proposed DAO framework. By building upon the methodological framework established in this chapter, the literature review will contribute to a optimized and deeper understanding of the research topic, consequently enabling the development of an innovative and effective solution to enhance architectural design evaluation.

Chapter 3

Design evaluation in the architectural industry

Architectural design evaluation is an essential step in both the design and construction phases of a project as it ensures that the buildings and structures are secure, practical, and meet the needs of their intended users. It is a value-laden assessment of the outcomes, quality, functionality, effectiveness, and worth of the design [25]. Elbellahy [26] believes that architectural evaluation, which enables both parties to assess the quality of the final result, plays a significant role in the learning and teaching process. Eilouti [25] believes that architectural evaluation is essential for both knowledge sender and receiver in the evaluation process. It is crucial for the knowledge recipient to be aware of their design skill levels, areas for progress, gaps in their knowledge, and abilities that require further work. To evaluate anything is to make a considered decision about how effective it is in a given administrative process. Evaluation is also the precise and rigorous application of systematic methodologies to judge a project's conception, execution, progress, and/or results [60].

In general, evaluation is a type of action that manages an object system's attribute-value in accordance with certain objectives and converts it into an objective, quantitative evaluation or utility. The comparison and evaluation of different proposals for solutions to design challenges is referred to as design evaluation. By systematic design review and audit, design evaluation is an efficient way to make sure that design items meet the end aim [71].

Reeve and Peerbhoy [55, 59] both believe that the main goal of evaluations of architectural designs is to promote reflection and aid in the recognition of future change and progress, in addition to learning about previous or present solutions. According to Hurteau et al.[37], the primary goal of a product evaluation is to assess the product's performance in order to assess its quality. Evaluation is a quantified standard used by educators to assess the effectiveness of teaching and learning. Evaluation is hence a product-oriented rather than a process-centered act, in contrast to assessment. Moreover, evaluation is the process of watching and measuring a setting in order to judge its quality and establish its "worth," either through comparison to similar things or to a predetermined set of standards [25].

3.1 Forms of evaluation

There are many forms of architectural design evaluation, Jury format, as one of the most common rituals of architectural design evaluations, represents the primary interface between critics and learner [48, 73]. And Webster [73] found that, in this format, both evaluation and education are carried out simultaneously in the most well-established performative stage of design education . In addition to the jury format, there are four other important evaluation approaches for architectural designs: one-to-one critique, peer evaluation, online evaluation, and anonymous review. In individualized critiques, instructors provide feedback and evaluation to each student based on their performance. In peer evaluation, students evaluate each other's work to provide effective and formative feedback and reflections [31, 52, 65, 67].

Online evaluation is another form of evaluation where evaluators and the evaluated share products and presentations in cyberspace asynchronously or synchronously [35, 42, 54]. Anonymous review is typically used in competitions to select candidate designs based on prescribed criteria without the presence of designers [19].

3.2 Existing problems

Albukhari [2] discovered, however, that the evaluation of design products is mostly influenced by the evaluator's cultural paradigm and personal preferences, which makes the process and outcomes of architectural design review primarily subjective. Therefore, developing an objective framework for assessing both qualitative and quantitative design criteria is always preferable . The design assessment literature has introduced a few evaluation tools, one of which was developed by Gann et al [30]. Eilouti [25] discovered that although it is a useful tool for evaluating architectural designs, some crucial aspects of architectural design are not covered by it. These include design communication skills, design presentation skills, design processing and development aspects, and the semantic and concept-related elements that typically form the basis of a design product and implicitly influence its outcomes. Moreover, Dounas et al.[20] discovered that, in a work context, architectural design valuation frequently emphasizes the cost of a structure rather than the value of the act of design. The project owner frequently attaches design value to the design specification in relation to cost rather than other crucial factors like design quality, building performance, and sustainability, as he believes that architectural design is not a solitary act, involves a variety of stakeholders, and in most cases encompasses groups of architectural designers working together to achieve a common goal. In this way, design principles are motivated by a client's requirement specification to reduce costs. Instead, according to Dounas et al. [21], the relative performance of many parameters and competing aspects that are naturally present during the design process should be used to compare and evaluate the objective value of architectural designs. Hence, giving one parameter priority over another creates value in the design.

Chapter 4

Blockchain and Decentralized Autonomous Organization (DAO)

Before going deeper into the concept of a DAO, it's important to understand the fundamentals of blockchain technology. This is because blockchain technology acts as the DAOs' operating system and records all of the DAO's transactions and decisions in an immutable manner. This chapter will elaborate on blockchain technology in 5 parts: blockchain basics, blockchain core components, blockchain applications, blockchain token fundamentals, and the benefits of blockchain to give a general understanding of how blockchain technology facilitates the implementation of DAOs and responds to the research questions of this study. This chapter will just address the fundamental ideas of blockchain technology and the key information for this research due to page limitations.

4.1 Blockchain

4.1.1 Blockchain overview

Blockchain, as a novel technology, has received significant attention in recent years because of the emergence of bitcoin. Blockchain was firstly mentioned in the white-paper, 'Bitcoin: A Peer-to-Peer (P2P) Electronic Currency System' in 2008 [50], written by Nakamoto, [1]. At the time, blockchain technology was first used as a peer-to-peer ledger for registering bitcoin transactions [45]. But in recent years, blockchain-based applications have sprung up, covering numerous fields including financial services, reputation systems, and the Internet of Things [79]. The blockchain is a decentralized distributed ledger consisting of a number of blocks organized in a chain. Each block contains data and a cryptographic hash pointer, creating a unique code generated by a hash function. The data inside a block in a blockchain can be anything like bank transactions, backup data, called function and code etc., which are recorded chronologically and publicly. This ensures the security of the data inside the blockchain [45]. In the following sections, the essential blockchain features that hold significant importance to this research will be explored and discussed, and the relevance between blockchain technology and decentralized autonomous organization will also be revealed before the discussion of DAO concept.

[1] Satoshi Nakamoto is the name used by the unknown person or group of people who brought the idea of bitcoin to public and authored the bitcoin whitepaper: 'Bitcoin: A Peer-to-Peer Electronic Cash System' [50]

4.1.2 Blockchain features

Transparency

Transparency is a key feature of blockchain technology, it refers to the visibility of transactions and data on the blockchain network. This transparency, prominently embodied in the availability of a public ledger, is instrumental in fostering trust among participants and deterring fraudulent activities. Each transaction is recorded on this public ledger, which can be viewed by all network participants, making every action transparent and independently verifiable [6, 9, 27].

The transparency of blockchain can also extend to the preservation of immutable transaction histories. Transactions are recorded in blocks, which are chronologically added to the blockchain, creating a permanent, unalterable history [44]. Each block also contains a cryptographic hash of the previous one, making it nearly impossible to modify a transaction without altering all subsequent blocks [63]. To ensure validity and authenticity of transactions, blockchain networks use consensus algorithms, requiring majority agreement before a transaction can be included in the blockchain [77].

Decentralization

Decentralization stands as a core feature of blockchain technology, fundamentally altering traditional approaches to authority, decision-making, and operational activities. Unlike traditional centralized systems, where a single entity or authority exerts control over the entire network, a decentralized blockchain network operates on a peer-to-peer basis, with each participant, or node, sharing equal authority [57, 15, 64]. The central authority in a conventional system, responsible for validating and recording transactions, maintaining security, and dictating the system's rules and operations, often risks a single point of failure, misuse of power, and lack of transparency [75].

On the other hand, the distinguishing attribute of blockchain technology is its decentralization, which delegates tasks and authority across the entire network of participants. Every node within the network maintains a complete copy of the blockchain and possesses the ability to independently verify and record transactions. This dispersion of authority negates the necessity for a central governing entity and reduces the danger of a single point of vulnerability, thereby augmenting transparency since all transactions are accessible and visible to all participants within the network [39]. The increased security this structure provides is a beneficial byproduct; it diminishes the vulnerability to targeted attacks on a central authority, and the independent verification conducted by each node makes it exceptionally challenging to forge transactions or tamper with the historical records on the blockchain [18].

However, true decentralization in a blockchain network is not without its challenges, and factors such as the distribution of mining power and the design of the consensus protocol can greatly impact the level of decentralization. Nevertheless, despite these hurdles, the pursuit of decentralization remains a crucial goal and a major selling point for blockchain technology [12].

Automation

Blockchain's automation is deeply intertwined with the concept of smart contracts. These self-executing contracts encapsulate the terms of an agreement in code, bypassing the need for manual oversight or a third party. Acting as a core feature of several blockchain platforms like Ethereum, smart contracts are instrumental in automating a multitude of processes in blockchain applications [58, 38]. They trigger transactions autonomously when predefined conditions are satisfied, enabling actions like transferring cryptocurrency, recording data, or setting off other smart contracts [11].

In the field of Decentralized Autonomous Organizations, smart contracts take on even more substantial roles. They are capable of automating a variety of organizational processes, such as allocating funds based on voting outcomes, enforcing rules and regulations, or regulating access to resources [29]. The incorporation of smart contracts enhances efficiency and diminishes the likelihood of human errors, promoting fairness and transparency.

However, smart contracts, being code-based, are not without their vulnerabilities. Errors in the code or undetected loopholes can lead to unforeseen consequences, which underscores the importance of thorough testing and auditing of smart contracts prior to deployment [46]. Despite these potential challenges, the automation achieved through smart contracts continues to play a pivotal role in maximizing the utility and effectiveness of blockchain technology.

4.1.3 Relevance between blockchain and DAO

DAOs are fundamentally built upon the principles and features of blockchain technology and DAOs are essentially organizations that are governed by smart contracts and operate on blockchain technology, which provides a transparent, secure, and decentralized infrastructure for their operation [70].

The inherent features of blockchain technology such as decentralization, transparency, and automation are integral to the functioning of DAOs. Decentralization allows for the distribution of authority and decision-making within the DAO, aligning with the principle of DAOs advocating for a democratic and decentralized decision-making process. Transparency ensures that all transactions and decisions made within the DAO are open and visible to all members, fostering trust among participants [62]. Automation, facilitated by smart contracts in blockchain, allows for the execution of tasks and enforcement of rules within the DAO without the need for human intervention, enabling the organization to operate autonomously [32].

4.2 Decentralized Autonomous Organization (DA0)

4.2.1 Definition of DAO

A DAO, which stands for Decentralized Autonomous Organization, is a novel organizational structure that leverages blockchain technology to enable individuals to self-govern and coordinate their actions through a series of self-executing rules that are encoded in smart contracts and deployed on a blockchain, until this day, the most popular blockchain used for deploying smart contract and governance of DAO is Ethereum. The decentralized nature of a DAO results in a governance structure that is fully decentralized. [33]. DAOs are entities that employ blockchain applications to facilitate member interactions, with predetermined rules and behaviors encoded in the source code. DAOs are designed to operate independently, possessing the capacity to recruit talents, offer services, and facilitate collaborative efforts among individuals [28]. In an ideal DAO, there exists no central authority or hierarchical management structure, as the organization's fundamental management and operational protocols are established through group decision-making processes and are encoded within its source code. Once deployed on a blockchain, these protocols become immutable. Furthermore, The absence of a central authority in a DAO is a defining and pivotal feature of this innovative system. By removing a central authority or hierarchical management structure, DAOs essentially democratize decision-making processes, allowing members to participate equally and directly in all critical decisions. This characteristic resonates with the very essence of decentralization, promoting transparency, equality, and mutual collaboration among participants. Moreover, decentralization eliminates the risk of a single point of failure, enhancing the system's resilience and reliability. By embedding the organization's management and operational protocols in the blockchain-based source code, they become immutable and tamper-resistant, further promoting trust and reliability within the system [72, 62, 3].

4.2.2 Comparison between DAO and traditional organizations

The concept of DAO is different from that of traditional organizations in so many ways, not only in their organization structures (Figure 5), but also in their operations, governance, and decision-making processes. Here is a comparison between the DAO and a traditional organizations [3].

- **DAO**

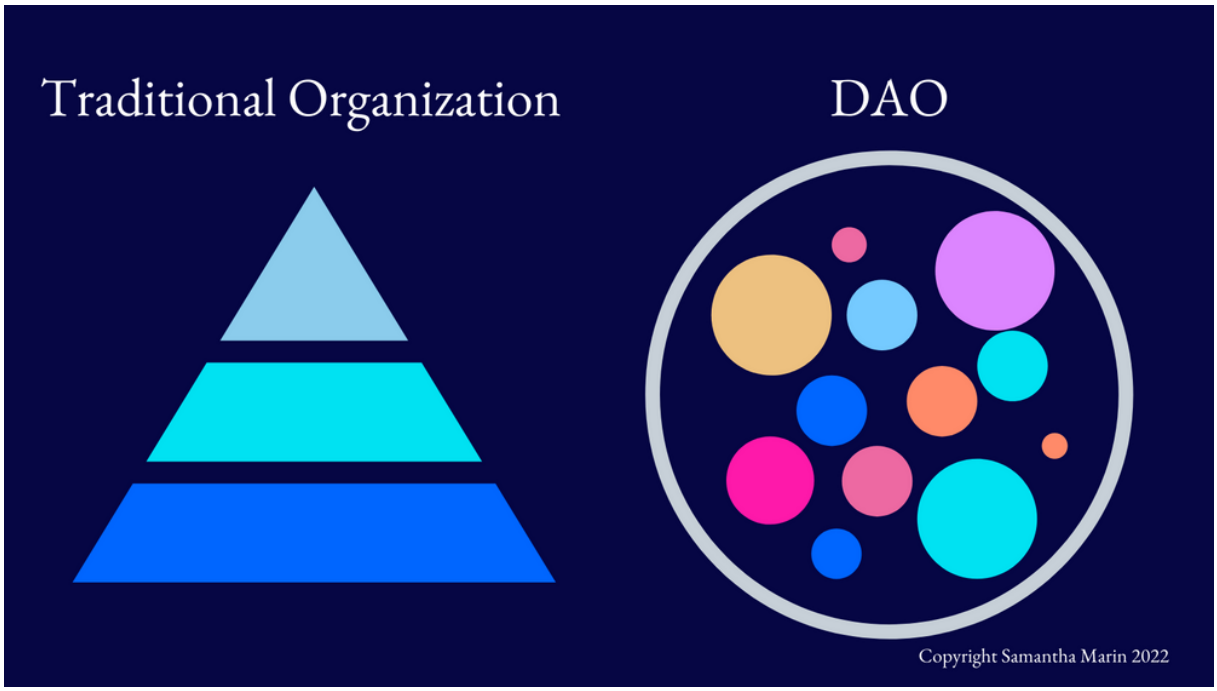


Figure 5: Comparison between DAO and traditional organization

1. The management inside a DAO is fully democratized, the decision are made in a collective approach where every member shares the equal voting power.
2. Decisions are made collectively by taking votes from members before any modification to be executed.
3. The execution of voted modifications and actions are automated without the need for the presence of a responsible third party.
4. The provided services inside the DAO are managed automatically and decentralized.
5. The operation and governance process are fully public and transparent.

- **Traditional organization**

1. Hierarchical organization structure.
2. Changes inside the organization can be required from a single third party.
3. Involves lots of human interactions.
4. Private and limited to public activity.
5. Small parties usually hold significant powers within the organization.
6. Decisions are made from a top-to-bottom approach.

4.2.3 Essential characteristics of DAO

Apart from the characteristics that distinguish the DAO from traditional organizations, the DAO possesses a number of unique characteristics that make it an efficient and effective type of organization. Wang [72] summarized a number of DAO characteristics in their study:

Decentralized

A traditional organization generally follows a top-down hierarchy structure with centralized authority. However, there is no such central authority and hierarchical structure in a DAO because the mission of

a DAO is to achieve completely bottom-up interaction, coordination among distributed or decentralized networks or nodes across the organization. As a result, the relationship and connection among nodes and people are no longer administered by the organizational structure set but follow the principles of equality, voluntariness, shared mission, and mutual benefits.

Autonomous

In an ideal DAO, all of the operations and governance processes follow the principles of 'code is law', as the operation and governance protocols are encoded into smart contracts and publicly deployed on blockchain. It makes sure that power is no longer centralized like traditional organizations and management is no longer based on a bureaucratic system but on community autonomy. In addition, the executive operation and governance protocols are agreed by all stakeholders before they are implemented through smart contract, therefore, consensus and trust within a DAO which are easier to be achieved within a DAO, therefore, the trust costs, communication costs, and transaction costs would be minimized.

Organized

A DAO is organized and ordered due to the use of smart contracts and established operation and governance protocols. The operational and governance protocols are reviewed by all stakeholders within the DAO before implementation and provide a clear framework for decision-making and execution. This allows for a more streamlined and efficient process because all participants are aware of their responsibilities and the steps required to achieve the DAO's shared mission. Furthermore, the use of blockchain technology ensures transparency and immutability, ensuring that all actions and decisions within the DAO are recorded and cannot be changed without consensus from stakeholders. This fosters a level of trust and accountability that is not always present in traditional organizations.

4.2.4 Core technologies

The fundamental technologies that support blockchain, such as cryptographic hashing and distributed consensus algorithms, form the basis for all blockchain-based applications, and Decentralized Autonomous Organizations (DAOs) are no exception. These technologies ensure that the defining characteristics of DAOs - transparency, immutability, decentralization, and application diversity - can flourish on the blockchain platform [47]. Although blockchain is the main network that DAOs operate on, as detailed in the literature review chapter, several other technologies also significantly influence DAOs' design and development, in the context of this research, these include smart contracts, Ethereum token standards, and the concept of Decentralized Identity (DID). Additionally, the core technologies that are going to be introduced are all included in the Ethereum network, the most popular blockchain platform, in recent years, for deploying Decentralized Autonomous Organizations (DAOs) because of its robust and flexible infrastructure, coupled with its Turing-complete programming language, allows for the creation of complex smart contracts, which are fundamental to the operation of DAOs. Furthermore, Ethereum's token standards, particularly ERC-20 and ERC-721, have become widely adopted in the DAO space. These standards ensure interoperability among various Ethereum tokens, allowing for seamless interaction between different DAOs and other decentralized applications (DApps) on the Ethereum network [66].

Smart contract

Smart contracts are autonomous, self-executing contracts with the terms of the agreement directly written into lines of code. They are programmable contracts that automatically execute and enforce agreements when predetermined conditions are met [13]. These contracts are the backbone of DAOs, facilitating their management operations and rule enforcement, eliminating intermediaries' need, and enabling trustless interactions among participants. Various DAOs, including Decentraland, FriendsWithBenefitsDAO, and SuperRare as mentioned in previous chapter, all employed smart contracts for many different purposes

ranging from asserting asset ownership and managing memberships to orchestrating governance mechanisms. Smart contracts provides them with a trustless and efficient method of managing operations and enforcing rules within the DAO, thereby obviating the need for intermediaries and reducing the chances of corruption or mismanagement [8].

Ethereum Token Standards

The domain of DAOs and architectural design evaluation can benefit from various Ethereum token standards such as ERC-20 and ERC-721. These standards provide a basis for creating fungible tokens (interchangeable tokens of equal value) and non-fungible tokens (NFTs; unique tokens of distinct value), respectively. Within the framework of an architectural design evaluation DAO, these tokens could serve functions such as establishing participatory governance, incentivizing contributions, and representing design ownership [51]. For instance, ERC-721 tokens could be used to symbolize ownership of unique architectural designs within the DAO, similar to how Decentraland employs ERC-721 (LAND tokens) to indicate virtual land parcel ownership. On the other hand, ERC-20 tokens, utilized by platforms like FWB (Friends With Benefits) and SuperRare, could be used for facilitating governance mechanisms in the architectural design evaluation DAO and incentivizing architects for their creative inputs. Hence, these tokens not only represent digital asset ownership but can also serve as a tool to enhance engagement and participation within the architectural design evaluation DAO, thus promoting a more decentralized, transparent, and effective evaluation process.

Decentralized Identity (DID)

Decentralized Identity (DID) is an innovative concept that allows individuals or entities to establish self-sovereign, verifiable identities that exist independently of any centralized authority or intermediary [68]. DIDs can be used to authenticate and authorize individuals, enabling them to control their personal data and digital interactions. This concept, while not being implemented in its entirety within this research, has played a pivotal role in shaping the design of NFT-based membership system. It inspired a comparable solution to identify unique architects participating in the system, further leveraging the decentralized, trustless nature of blockchain technology to enhance the system's integrity and user autonomy.

4.2.5 Challenges and limitations

The previous chapters have illustrated the potential of the DAO as a novel organizational structure that integrates blockchain technology and decentralized governance. This structure has the capacity to enhance transparency, collaboration, and decentralization, while also optimizing efficiency and efficacy in conventional industries by leveraging established workflows. Nevertheless, DAOs encounter numerous challenges and limitations. The current state of blockchain technology, including its scalability, security, and interoperability with other blockchains, suggests that it is not yet prepared for extensive implementation. This chapter will examine the technical barriers and constraints that current DAOs encounter, along with their security and governance limitations, as well as the legal and liability challenges they face.

Technical challenges and limitations

A. Wright's [76] research highlights that while DAOs seek to simplify operational and management workflows in traditional industries or organizations through the use of smart contracts for automation and participatory governance for decision-making, they are not resistant to challenges as an organizational structure. The concept of code as law or regulation by code, proposed by DAO, has been extensively discussed by Wang et al.[72]. Although this concept shows potential, its practical implementation presents significant challenges. The main cause of this occurrence is the notable semantic distinction that exists between legal regulations in the physical world, commonly referred to as "wet code," and regulations expressed in programming code within smart contracts. To achieve greater versatility and objective results,

the former is frequently written at a high level of abstraction using ambiguous, flexible human language. In order to achieve a higher level of transparency, it is necessary to express the latter in semantically explicit codes, which should be composed using a strict, formal computer language. The translation process from wet code to dry code inevitably leads to ambiguity, which can result in unexpected outcomes and inconvenience for communities that adhere to the code is law principle. Moreover, certain instances entail wet codes that are exceedingly challenging to convert into dry code, thereby significantly restricting the progress, availability, and equity that a DAO could have provided to its supporters.

Security challenges and limitations

The issue of security has been an important topic within blockchain ecosystems, particularly in light of the hack of The DAO by an anonymous hacker, which led to a loss of $50 million. The issue of security has emerged as a primary area of concern for the majority of DAOs. Due to the immutability of smart contracts upon deployment, a considerable number of hackers are trying to capitalize on vulnerabilities within the smart contract. DAOs, however, are dependent on smart contracts for their functioning and management. Despite the significant progress made in the improvement of smart contracts and decentralized governance mechanisms aimed at enhancing the security of DAOs, the possibility of security breaches and loss of funds remains. As such, it is essential that DAOs remain proactive and vigilant in their attempts to secure their operations [72].

4.2.6 Governance challenges

DAOs face unique governance challenges because they operate on a decentralized and democratic system. One of the most difficult challenges is reaching agreement among members who have opposing viewpoints and interests. This can cause decision-making delays and, in some cases, deadlock. Furthermore, voter apathy or low participation rates among token holders may exist, resulting in the dominance of a small number of token holders over decision-making. Another issue is the absence of legal frameworks and regulations governing DAOs, which can lead to uncertainty and potential legal issues. Finally, DAOs may face difficulties in maintaining transparency and accountability because decision-making processes and resource allocation are not always clear to all members [3]. Despite the fact that the DAO concept was created to optimize the governance structure and process of organizations, given its infancy in many aspects, the shape and dimension of an optimal governance structure for DAOs is far from settled. A set of blockchain infrastructures and derivative technologies such as smart contracts may have improved operational efficiencies by lowering the cost of democratic processes, but they have not eliminated the social and political dimensions of governance. Direct voting via distributed consensus, for example, requires DAO members to be constantly engaged and attentive to DAO activities on an ongoing basis. Furthermore, gathering all of the necessary information for making an informed decision for the entire community may prove to be time-consuming and complex, discouraging participation [76]. According to Altaleb and Zoltan's [3] research on the importance and applications of blockchain governance, there is currently no universally accepted framework for comprehending blockchain governance, and there is a phenomenon that is contrary to popular belief about DAO, the existing governance within a DAO is frequently and not entirely technologically encorded or self-governed autonomously. According to one of their research interviewees, "nowadays, we see off-chain governance largely," and not all proposed on-chain governance models are feasible in practice because consensus for decisions is easier to establish when it does not concern on-chain governance. Furthermore, governance processes become complex as a result of blockchain's decentralized nature, immutability of code, lack of organizational and business structures, autonomous participants, and entanglement of application and fragmented infrastructure pieces. And this entanglement revealed that application governance is inextricably linked to infrastructure governance. In many cases, different stakeholder groups influence infrastructure governance, resulting in a general lack of effective governance initiatives.

Legal and liability challenges

The legal and liability challenges of DAOs are still a topic of debate and discussion among scholars and practitioners because the DAO, as a new type of organization, has an unclear legal status due to characteristics that distinguish it from traditional organizations such as decentralization, cross-border, and anonymity. It is difficult for law enforcement departments to trace accountability if legal issues arise during operations. DAO, on the other hand, has not been clearly defined at the legal level [72]. And A. Wright [76] agrees that the DAO lacks all forms of legal recognition, potentially exposing DAO community members to organizational liabilities and responsibilities. Furthermore, as an organization, DAO remains outside of traditional legal systems, limiting its ability to transact with more traditional legal enterprises. And Wright believes that, from a legal standpoint, one of the longstanding benefits of forming a legal entity is the ability to protect personal assets or to be protected from the legal system when lawsuits are filed against the entity; however, DAO does not enjoy these benefits by default because it is not recognized by traditional legal systems as a legal entity eligible for the limited liability regime.

4.3 Relevance between blockchain, DAO and architecture industry

The research will explore and demonstrate the relevance and connection between the blockchain, the DAO concept, and the architectural industry. In addition to being fundamental technologies, blockchain and DAOs have the potential to significantly transform the AEC sector. Additionally, a number of researchers have looked into this transformative connection and collaboration in a number of environments.

Researchers at TU Wien [69] believe that blockchain technology and the new organisational structure like DAO could revolutionise the Architecture, Engineering, and Construction (AEC) industry in the pursuit of better collaborative processes in the AEC sector. They emphasise that adopting blockchain requires a change in governance and organisational structure, moving away from conventional management procedures and towards DAOs. Their work provides a conceptual framework that aims to simplify the comprehension and application of blockchain technologies and DAOs in the AEC sector, enable better collaborative processes, and provide competitive advantage. It also serves as a manual for practitioners and researchers on how to modify conventional organisational design principles to accommodate the implementation of blockchain technologies and DAOs in the AEC sector.

In a different paper, dounas [21] explains how blockchain can serve as a stigmergic information layer for building collective digital factories by way of smart contracts and tokenization. He focuses on how various design tools and agents are coordinated when designing buildings. They contend that stigmergic coordination could be operationalized in the AEC sector through token incentive mechanisms in a manner akin to cryptoeconomics. They predict that this approach could boost productivity, reduce waste and carbon emissions across the board, and enable decentralised governance through smart contracts.

In the case of "ArchiDAO," a case study about using a decentralised autonomous organisation (DAO) in collaborative architectural design presented by Dounas [22] the researchers present an architecture studio that is run using smart contracts on the Ethereum blockchain. By using stigmergic principles implemented on smart contracts, they provide a framework for changing the way architectural work is done. In order to identify a set of stigmergic principles, this work conducts a thorough analysis of the Viable System Model, collective authorship in architectural design, and previous DAO software stacks.

Last but not least, a paper outlining blockchain's potential for the construction industry [36] claims that blockchain offers a chance to develop novel ways of economic coordination that will improve collaboration within and across the phases of the built asset life cycle. They contend that the development of novel economic coordination represents blockchain's disruptive potential and advances the idea of blockchain as an institutional innovation in the construction sector. They suggest a framework for adoption that can direct academics and professionals as they investigate the potential of blockchain technology and cryptoeconomics for the building sector.

4.4 Summary

This chapter introduces DAOs, as well as their characteristics, operations, and governance protocols. It includes a comparison of DAOs to traditional organizations as well as specific characteristics that distinguish DAOs. The chapter also delves into the roles and responsibilities of DAO members, the blockchain technologies used, and the governance and tokens involved. It also highlights some of the most successful DAO examples and their applications in various industries. The chapter concludes with a discussion of the challenges and limitations that DAOs face, including technical, security, governance, and legal and liability issues. According to the literature review on the investigation of DAO, DAOs are a relatively new type of organization that incorporates blockchain technology and decentralized governance. They are intended to promote transparency, collaboration, and decentralization while improving efficiency and effectiveness in traditional industries' existing workflows. However, DAOs continue to face numerous challenges and limitations, including technical challenges and limitations, security limitations, governance challenges, and legal and liability challenges. Despite these obstacles, DAOs have demonstrated significant potential in a variety of industries and have grown in popularity in recent years.

Chapter 5

Interview with architects

5.1 Overview

There are two main reasons for conducting interviews with architects to address the topic of architectural design evaluation. Firstly, the limited existing literature on this subject results in a lack of support for identifying the problems and challenges faced by the architectural industry. This insufficiency of knowledge and information makes it difficult to develop comprehensive artifact and methodologies for evaluating architectural designs and solve the problem. By interviewing architects with hands-on experience in architectural design and evaluation, a deeper understanding of the problems and challenges at hand can be obtained, thus contributing to the expansion of knowledge in this area. Secondly, there is often a gap between theory and practice in the architectural field, which can hinder the effective implementation of design evaluation methods. Interacting with industry professionals through interviews allows for the acquisition of valuable insights directly from the practitioners who confront these challenges on a daily basis. This process of gathering information from the architects themselves not only helps bridge the gap between theory and practice but also provides a more accurate representation of the real-world scenarios faced by architects during design evaluations. Consequently, these interviews serve as a crucial tool for enhancing the overall understanding of architectural design evaluation and informing the development of improved methodologies in the future.

5.2 Interview objectives

The interviews will be designed and conducted by centering around understanding the status quo of architectural design evaluation and exploring the potential integration of the DAO in the evaluation process. The interviews with experienced architects will serve as a crucial tool to achieve these objectives by addressing the following key areas:

1. Exploring the significance of architectural design evaluation for architects in professional environment
2. Identifying the challenges and difficulties architects encounter in the architectural design evaluation process.
3. Investigating architects' expectations and requirements for an ideal design evaluation approach.
4. Assessing the potential need for a DAO in helping architects realize the objective value of their designs.

Through fullfilling of these objectives, the interview aims to contribute valuable insights and understanding to the architectural design evaluation field and inform the development of improved methodologies that can effectively bridge the gap between theory and practice.

5.3 Interview design

5.3.1 Methodology

The semi-structured interview methodology was chosen for this study because of its flexibility and ability to facilitate in-depth exploration of architects' perspectives on design evaluation and the potential integration of a DAO. This section elaborates on the key features of the semi-structured interview methodology. Semi-structured interviews enable the researcher to maintain a clear research focus while still allowing participants to express their thoughts, experiences, and opinions in a more open and conversational manner [17]. This approach strikes a balance between structured interviews, which may be too rigid and limiting, and unstructured interviews, which can be too open-ended and unfocused. The flexibility of semi-structured interviews ensures that participants have the freedom to delve deeper into specific topics of interest, offering richer insights for the researcher. According to Adeoye-Olatunde and Olenik [1], semi-structured interviews are a preferred data collection method when the goal of researchers is to better understand participants' unique perspectives rather than obtaining a general understanding of a specific subject or questions. In the context of this study, the semi-structured interview method is particularly suitable as it allows architects to share their individual experiences, challenges, and opinions regarding design evaluation and the potential role of DAOs.

5.3.2 Interview candicates

To obtain valuable and insightful understanding to the topic, it is crucial to select the right interview candidates who possess the appropriate background and experience in the field of architecture. This paragraph introduces the key selection criteria for identifying suitable candidates for semi-structured interviews. The following criteria have been established to ensure that participants are well-equipped to provide informed perspectives on architectural design evaluation and the potential integration of decentralized autonomous organizations (DAOs):

1. Architectural Education Background: Candidates should possess a formal education in architecture, which may include a bachelor's or master's degree in the field. This criterion ensures that participants have a foundational understanding of architectural principles, design methodologies, and evaluation techniques.

2. Professional Experience: Candidates should have worked as architects in a professional environment either with a full-time position or an internship, gaining practical experience in designing, evaluating, and executing architectural projects. This criterion ensures that participants can share their firsthand experiences and insights regarding the challenges and limitations of current design evaluation approaches.

3. Additional criteria may include involvement in diverse architectural projects, familiarity with emerging technologies in architecture, or experience in collaborating with interdisciplinary teams, varied size of architecture project. These criteria can help ensure that participants bring a diverse range of perspectives and experiences to the study, enriching the overall understanding of the research topic.

5.3.3 Interview questions

The researcher will follow the interview guide, asking open-ended and pre-defined questions and moving deeper into specific topics as needed. Actively listening and taking notes will be required to ensure that the information provided by participants is accurately recorded. To encourage open and honest responses from the architects, the researcher will maintain a neutral and non-judgmental attitude. This section provides an overview of the interview questions and discusses the motivations behind the designed interview questions, highlighting their significance in addressing the research objectives.

There are five main subjects that need exploring over the interviews that are defined through previous literature study and knowledge gap between literatures and real-world practices. These subjects aim to define key aspects of architectural design evaluation and the potential implementation approach of a DAO-based system:

1. Determinants of Success of architectural designs: This subject investigates the architects' perspectives on the factors that contribute to the success or quality of their designs. It aims to understand the components and aspects that architects prioritize when evaluating their own work.
2. Existing design evaluation process: This subject explores the current processes and participants involved in the architectural design evaluation, providing a baseline for comparison when considering the potential implementation of a DAO-based system. It also investigates the architects' comfort level with external organizations participating in the evaluation process.
3. Attitude or satisfaction towards existing design evaluation approach: This subject examines architects' satisfaction with the current evaluation approach, aiming to identify the strengths and weaknesses of the existing system and determine what features should be retained or improved upon when considering a DAO-based system, also retrieves the strengths of existing system and apply them into the future DAO framework.
4. Subjectivity in design evaluation: This subject delves into the potential subjectivity and bias in architectural design evaluation, aiming to uncover the sources of these biases or subjectivities and assess whether a DAO-based system could help to mitigate or eliminate such issues.
5. Expectation to future design evaluation approach: This subject investigates architects' expectations for future evaluation approaches, exploring their desired focus and criteria in order to assess whether a DAO-based system aligns with these expectations and could offer a suitable alternative to current evaluation methods.

Following the intentions and subject defined above, the interview questions are designed and organized as follows:

1. As an architect, how do you evaluate the success or quality of your designs?
    - Do you think the acceptance from your colleagues means/stands for the success of your design?
    - What are the components/aspects do you care about when it comes to evaluating your architectural designs?
2. What is the process of the existing evaluation approach of architectural designs?
    - Who are the participants in the evaluation process of your architectural designs?
    - Are there any colleagues from other departments/participants from external organizations?
    - Are you comfortable with people from external organizations evaluating your designs?
3. Are you satisfied with the existing approach to architectural design evaluation?
    - If yes, why do you think it is a great approach? Which aspects does it focus on? What is the most important reason you like it?
4. Have you ever encountered situations where you felt that the evaluation of your architectural designs was subjective or biased?
    - If so, where do you think those biases or subjectivities come from?
    - What do you think are the limitations of current approaches to realize the objective value of architectural design?
    - Are the limitations or problems at a personal or system level?
5. What evaluation approach are you expecting in the future when it comes to evaluating your designs?
    - What aspects should it focus on?

- What components/criteria should it include?

6. Do you want the intellectual property (IP) of your architectural design to be protected through public licensing?

However, the interview questions will not be asked in exactly the same order as they are presented above. Instead, the order will be adapted depending on the actual situation during the interviews. This approach allows for a more flexible and organic conversation with the architects, ensuring that their thoughts and insights can be captured as naturally and accurately as possible. By following the semi-structured interview format, the researcher can maintain a clear focus on the main subjects while still allowing participants to express their thoughts, experiences, and opinions in a more open and conversational manner. This approach ensures that the interviews remain engaging, productive, and relevant to the research objectives, while also accommodating the unique perspectives and experiences of each architect in the individual interview.

5.3.4 Recording and Transcribing the Interviews

The interviews will be audio-recorded with the participants' permission to facilitate accurate transcription and data analysis. The recordings will be transcribed to ensure that the responses are accurately represented, capturing the precise words used by the architects. To protect the participants' privacy, any identifiable information will be anonymized during the transcription process, including the removal or alteration of names, company names, project names, or other potentially identifying information. By implementing these measures, the researcher aims to create a transparent, accurate, and ethically sound record of the interviews, supporting the subsequent data analysis and interpretation process in pursuit of addressing the research objectives.

5.3.5 Data analysis

The transcribed interviews will be analyzed using thematic analysis methodology, a qualitative data analysis method that involves identifying, analyzing, and reporting patterns (semantic themes) within the data [7]. To carry out this analysis, a qualitative data coding approach will be employed. This approach involves systematically reviewing the data, assigning codes to significant segments, and subsequently grouping these codes into broader themes that capture the essence of the architects' perspectives. By using thematic analysis and coding, the researcher can effectively organize the data into meaningful categories and draw conclusions about the architects' perspectives on architectural design evaluation and the potential implementation of a DAO-based system. This method enables a comprehensive understanding of the challenges and limitations faced by architects in the current architectural design evaluation process, as well as their potential need to a more effective and efficient system, in the context of this research, a DAO-based approach to enhance collaboration and objectivity in the field.

5.4 Interview results

Throughout the research process, a total of 6 architects in the architectural design industry were interviewed. These interviews were conducted in a hybrid manner, either in person or through online meetings. The interviewees have provided valuable insights on the research topic, offering valuable input for refining existing problems and expected features and potential improvements for the future approach. The artifact of this research benefited greatly from the architects' contributions. During the interviews, the architects shared their perspectives on the importance of the evaluation process and the intellectual property of architectural designs. The results of these interviews provide a comprehensive understanding of the current state and future direction of architectural design evaluation. The architects' feedback on the evaluation process highlighted a lack of focus on sustainability and circularity and dynamic change on evaluation standards, which they believe should be prioritized for every project in the industry. In addition, the architects were open to the idea of sharing their intellectual property with non-profit organizations like

universities or architecture design academies, showing a commitment to advancing the industry as a whole. Overall, the insights gained from these interviews provide a well-rounded understanding of the challenges and opportunities for the future of architectural design evaluation. The following section will include organized interview logs resulted from previous interviews, the full interview transcripts can be seen in the appendix (A-F) , the interview logs are organized to best represent interviewees' opinion and insights to certain subject and interview questions, such as the evaluation approach of architectural designs, the components and participants of the evaluation process and the limitation and expectation of evaluation approach.

5.5 Interviews summary

Interview A
Interviewee background : Previous lead architect, 10 years of experience being an architect, got involved in multiple medium-large sized project.

Interviewee A thinks that, during her previous working experience, the success of her architectural design is solely determined by the acceptance from his employers in terms of cost, budget, profit and whether it meets the deadline of the project, although she personally do not agree these should not be the only factors that set the success of an architectural design product. She thinks compliments from her colleagues will be pleasant to her and motivate her to push her career and skills further down the road. Regarding the existing evaluation approach, in her experience, there was basically no evaluation phase as once the design is finished, it will be saved in the company portfolio after being accepted by project owners, and sometimes there are some critics from project owners regarding budget, cost and adjustment, even there was, it was not helpful to her architectural design improvement. But she hopes to get feedback, constructive critisms from colleagues or people from external organizations that have experience or are professional in architectural field. As such, she is very dissatisfied with the existing evaluation phase in her architectural design phase as even there was an evaluation phase, it was about cost, budget and profit or any number matters, rather than functional requirements, sustainability or contributions to built environment and human beings which is more impactful in the long run. And she pointed out that, she would love to have these criteria or metrics as part of future evaluation approach. Finally, in terms of IP of her licenses, from the organization where she has worked for, there is no personal level of IP that belongs to architects, all product produced inside the company belongs to the company, also, finally, if there will be any IP licenced to architects, she would love to have it, and she think it is pleased to offer the license to organizations for educational purposes.

Interview B
Interviewee background: Architecture graduate student, 3 internship experience being an architect.

In the interview with architect Interviewee B, she explains that evaluating the success or quality of a design involves multiple factors such as the design's logic, concept validity, feasibility, and functionality. She also highlights the importance of acceptance from stakeholders, including managers, clients, and project owners, in determining the success of a design. While Interviewee B agrees that acceptance from colleagues can be motivating, she does not believe it solely determines design success. Interviewee B is unsure about the evaluation process in the existing architectural design workflow, as she has never participated in such a process. However, she suggests that stakeholders like clients, managers, project owners, and developers should be involved in the evaluation, assessing design implementation and functional requirements. She is also concerned with the subjectivity of some evaluation results, which may not reflect the true value of the project. Interviewee B believes that external organizations with professional experience or certification, such as Leadership in Environmental and Energy Design (LEED), could help evaluate designs objectively and add value to all parties involved. She hopes that future evaluation approaches will consider sustainability, , functionality, and feasibility. Lastly, Interviewee B emphasizes the importance of intellectual property (IP) protection for architects and their designs, and hopes that software can be developed to ensure proper protection and public licensing for architectural designs.

Interview C
Interviewee background: Architecture graduate student, 2 internship experience being an architect.

During the interview with Interviewee C, she was asked how she determines the success or quality of a design. She answered that the functionality of the design is crucial, and when she evaluates architectural designs, she looks at whether the project's objective or purpose has been fulfilled and the acceptance from clients, managers, and colleagues. She believes that the success of a design is determined by these two factors, and she finds encouragement and motivation from compliments and acceptance from colleagues, who review the designs before they are handed over to clients or managers. Interviewee C mentioned that she is an adaptive person and comfortable with the existing valuation approach for architecture design. She cares about the project objective and the design's functionalities and is accepting of feedback from clients, colleagues, and managers. She is open to evaluation by external professionals in the architectural field who have connections to her desires. However, she has encountered subjectivity in previous evaluation approaches, which she attributes to cultural backgrounds. She thinks that in the future, the criteria for evaluating designs should include how they are presented and rendered, and intellectual property should be a significant part of the evaluation approach due to its increasing importance in the workflow.

Interview D
Interviewee background: Previous lead architect, 5 years of experience being an architect in China, involved in multiple medium-large sized architecture project.

Interviewee D answered that as an architect, he evaluates the success and quality of his design based on a couple of factors. One of the most important factors is functionality which refers to the extent to which the design meets its intended purpose. Another factor is feedback from clients or end users, as know as the acceptance from the clients and users. In terms of acceptance from colleagues, he thinks it is very important to have it as an architect team always consist of architects with different expertise, so discussion and acceptance between each other will positively affect others over the process. The process of the existing approach involves a lot of reviews by team members, like architects, engineers, and other professionals, and consequently it will be handled to clients to see if the design fulfilled its purpose or objective, as well as other stakeholders. When asked about people who will evaluate his work from external organizations, he thinks that it is critical that this process will bring value to the whole company. It can be a source of improvement for the architect to improve his skills and for the company to help the success of the project. Thus, the person who evaluates the work should be someone who is very professional in the architectural field. In fact, in his previous experience, his project team always looked for consultancy when designing a project in terms of local culture, standards, structure expertises etc. So he is comfortable with working with external organizations but is not very satisfied with the existing approach of architectural design valuation due to the limitations in the existing approach. He thinks that the standards of architectural design should be evolving and dynamic all the time, but most companies and architectural firms have static standards and resistance to change. He believes that this is bad for the sustainability of the industry. In the future, he would like to put more emphasis on sustainability and social impact in the architectural design evaluation. Architects need to design buildings and spaces that are functional, beautiful, and contribute positively to the community and environment. Regarding the protection of design, he thinks that intellectual property protection for architectural design is necessary, but it is almost impossible to implement. Architects always borrow and have consultancy from external organizations, which make it difficult to protect the design. In terms of culture and local standard, he always reaches out to consultants to consult on some structures, like climate and local standards. He is an adaptive person, and whatever evaluation approach comes in the way, he is okay to work with it. However, there are limitations in the existing approach, and he thinks that these limitations and problems are at a system level.

Interview E
Interviewee background : Architecture graduate student, 3 years of experience being an architect, involved multiple small-medium sized project.

During the interview with our interviewee E, an architect, it was discussed that there are three main factors that determine the success of their designs. The first factor is whether the objective and goals were achieved within the limited budget set by the clients. The second factor is whether the design met the standards set by the architect for their architectural designs, and the last factor is the acceptance of clients. E checks the first two factors before presenting their designs to clients. When it comes to evaluating existing architectural designs, E usually seeks opinions from friends outside of their organization like his friends or people who he used to work with. E then consults with tutors, previous professors, and

teachers for feedback and insights to make improvements to the existing design before presenting it to clients. This means E is comfortable with external organizations evaluating their designs. However, E is not satisfied with the existing approach to architectural design evaluation. He explains that there was no formal design evaluation process in his previous organizations where he worked. E thinks that the existing evaluation approach lacks focus on sustainability and circularity, which are important factors for architecture design evaluation and should be highlighted for every project in their home country. E considers these limitations of the existing approach to realizing the objective value of architectural design. He believes that it is almost impossible to realize the true objective value of architectural design because everyone has their own standards. It is difficult to achieve the ultimate objective value of any architectural design both on a personal level, where everyone has their own taste and preference, and on a system level, where the whole industry standard is fragmented and constantly changing. In the future, E believes that it is necessary to include security and sustainability in the architectural design evaluation criteria. He think that these are important factors to consider. Regarding the intellectual property of their architectural design, E believes that it is acceptable to hand over the design or IP to non-profit organizations like universities or architecture design academies. He thinks that when their design is recommended or presented elsewhere, it signifies that their design was significant and meaningful, and he would feel proud of it.

Interview F
Interviewee background : previous independent architect, 2 years of experience, involved in multiple medium sized architecture project.

In the interview with architect Interviewee F, he identified personal perspective, client acceptance, and feasibility as the main aspects that determine the success or quality of his design. He did not consider acceptance from colleagues as a determining factor, since every architect has different tastes and personal perspectives. From his experience, there is no general evaluation process for architectural design, and he believes key components for evaluation should include personal perspective, feasibility, and compatibility with the local environment. Regarding seeking external advice, he is comfortable doing so if it relates to industrial knowledge. He is not satisfied with the existing approach to architectural design evaluation due to the subjectivity of evaluators but acknowledges the challenge of eliminating subjectivity. As for intellectual property (IP) in architecture, he finds it an interesting concept that could increase recognition and public impact of a design, although implementing IP for architects could be complicated.

5.6 Interview results coding

Over this chapter, the key findings from the previous interviews will be summarized and analyzed using qualitative coding approach to facilitate a better understanding of the existing problems and status quo of architectural design evaluation. Through the interviews with 6 professional architects in the industry, several problems have been identified and insights have been emerged, and the purpose of this analysis is to build a foundational base for the design of future architectural design evaluation approach by addressing the limitations and gaps identified in the existing approach.

5.6.1 Data processing

Before getting started with data analysis, the data from interviews will be processed first by qualitative coding approach. Qualitative coding is a method of categorizing data to identify patterns and themes that emerge from the data. It involves breaking down the data into smaller parts and assigning codes or labels to those parts based on their meaning and significance. This process allows researchers to identify recurring themes and patterns, as well as to identify areas of interest for further exploration. The qualitative coding process typically involves several steps, including familiarization with the data, developing a coding scheme, applying codes to the data, and reviewing and refining the codes as necessary. Once the coding process is complete, the data can be analyzed using various qualitative data analysis techniques, such as thematic analysis, content analysis, or discourse analysis [61]. In the context of this study, as the answers of interview questions from participants are part of their interpersonal experiences, culture values and personal worldviews, therefore, value coding will be the qualitative method of the

data coding in this research. Value coding is a qualitative method used to analyze data that is related to values and beliefs. It involves identifying the values that are expressed or implied in the data, and categorizing them according to different themes or dimensions. This approach is particularly useful for analyzing interview data, as the responses of participants are often shaped by their personal values, cultural background, and worldview [10]. Then, value coding will be used to analyze the interview data obtained from architects regarding the evaluation of architectural design. The aim is to identify the values and beliefs that underlie their opinions and insights, and to categorize them according to different themes or dimensions. This approach will enable the researcher to gain a deeper understanding of the factors that influence the evaluation result of architectural design, and to identify areas where improvements can be made.

5.7 Data coding

The codes of the qualitative data coding method are generated from part of the research questions as follows:

- What are the existing challenges in design evaluation for architects?
- What should architects expect from a new evaluation approach?

After that, two main themes emerged from the data analysis: Personal fulfillment and Systematic fulfillment.

Personal fulfillment refer to the individual needs and desires of architects in terms of their own personal growth and development as professionals. On the other hand, systematic fulfillment relate to the expectations of architects for a more comprehensive and objective evaluation approach that takes into account various aspects beyond just budget and profit and other expectations to systems like architectural firms, studios, and the industry.

The codes are defined as follows:

- Personal fulfillment
  - Success determinants of design
  - Intention to be evaluated by professionals
  - Demand for Intellectual property

The personal fulfillment theme includes three codes: Success determinants of design, Intention to be evaluated by professionals, and Demand for Intellectual Property. Success determinants of design refer to the factors that architects consider to be the main determinants of the success of their designs. Intention to be evaluated by professionals highlights the desire of architects to be evaluated by professionals in the field. Finally, Demand for Intellectual Property refers to architects' desire for ownership and protection of their intellectual property.

- Systematic fulfillment (until a better name comes out)
  - Satisfaction with existing evaluation approach
  - Expectation of objective design evaluation
  - Expectation of additional criteria/components in design evaluation approach

The systematic fulfillment theme includes three codes: Satisfaction with existing evaluation approach, Expectation of objective design evaluation, and Expectation of additional criteria/components in design

evaluation approach. Satisfaction with existing evaluation approach reflects the level of satisfaction architects have with the current evaluation approach. Expectation of objective design evaluation highlights the need for a more objective and comprehensive evaluation approach. Finally, Expectation of additional criteria/components in design evaluation approach refers to architects' expectation for the inclusion of additional criteria beyond just budget and profit in the evaluation approach.

Codes	Code in Personal fulfillments level		Code in System fulfillments		
Interviewees	Success determinants of design	Intention level to be evaluated by professionals	Satisfaction level to existing evaluation approach	Expectation level to objective design evaluation	Expectation to additional criteria/components in design evaluation approach
A	Profit, budget,deadline Stakeholders' acceptance	Strong	Low	Strong	More on functional requirements, sustainability and contributions to built environment
B	Stakeholders acceptance, functional requirement, feasibility	Strong	Medium	Strong	Involvement of stakeholders and functional requirements
C	Functional requirements, Stakeholders acceptance, project objective	Medium	Strong	Medium	More on design and development process
D	Functionality, stakeholders experience and acceptance	Strong	Medium	Medium	Dynamic standards, more on sustainability and culture value
E	Profit, budget, personal fullfillments and stakeholders acceptance	Strong	Medium	Strong	Sustainability and circularity
F	personal perspective, client acceptance, and feasibility	Medium	Medium	Strong	Personal perspective, feasibility, and compatibility

Figure 6: Coded interview results

Personal fulfillment

The first theme of the qualitative data coding is "Personal fulfillment," which includes three codes. The first code is "Success determinants of design," which refers to the factors that architects consider to define the success or quality of their designs. The data analysis revealed that architects generally consider meeting the client's objectives and staying within the limited budget to be the primary determinants of success. However, they also place importance on meeting their own standards for architectural design. The second code is "Intention to be evaluated by professionals." Architects in the interviews expressed their desire for professional feedback and evaluation of their designs. They see this as an opportunity to improve their skills and knowledge of architectural design, and to receive recognition from peers in the industry. This code suggests that architects have a personal need for validation and recognition for their work. The third code is "Demand to Intellectual property." Architects expressed a desire to have ownership and control over their designs. They see their designs as valuable intellectual property and want to be compensated for their work. This code suggests that architects have a personal interest in protecting their creations and benefiting financially from their work.

Systematic fulfillment

The second theme of the qualitative data coding is "Systematic fulfillment," which includes three codes. The first code is "Satisfaction with existing evaluation approach." The data analysis revealed that architects are generally dissatisfied with the current evaluation approach in the industry, which is focused on cost, budget, and profit. Architects feel that these metrics do not adequately capture the value of their designs, and they desire a more holistic evaluation approach. The second code is "Expectation of objective design evaluation." Architects want a more objective and standardized evaluation approach that focuses on the functional requirements, sustainability, and contributions to the built environment and human beings. This code suggests that architects want a more scientific and rigorous approach to design evaluation. The third code is "Expectation of additional criteria/components in design evaluation approach." Architects expressed a desire for the evaluation approach to include additional criteria and components, such as the impact on the local community, the environmental impact, and the social impact. This code suggests that architects want a more comprehensive evaluation approach that takes into account the broader implications of their designs. Overall, the themes and codes revealed in the qualitative data coding provide valuable insights into the needs and expectations of architects regarding the evaluation of their designs (Figure:6). The findings suggest that architects have a personal need for validation and recognition for their work, as well as a desire to protect their intellectual property. They also want a more holistic, objective, and comprehensive evaluation approach that takes into account the broader implications of their designs. These insights can inform the development of a new evaluation approach that better meets the needs of architects and the industry as a whole.

5.8 Personal fulfillment analysis

In personal fulfillment level (Figure:6), all of the interviewed architects agrees that one of the most important success determinates of their designs is the acceptance of stakeholders such as clients, managers and team leaders. However, the concept of acceptance can be further broken down into various components. For instance, Interviewee A expressed dissatisfaction with the acceptance of her previous designs, stating that they were based solely on meeting clients' and employees' expectations for profit, budget, and deadlines. Conversely, Interviewees B and C emphasized that acceptance could also be achieved by fulfilling functional requirements and ensuring the feasibility of the design. Furthermore, some of the interviewed architects also emphasized the importance of their own design standards, which include aesthetics, cultural values, and personal challenge goals. For instance, Interviewee E highlighted the significance of meeting their own design standards, which are often influenced by their personal beliefs and values. Similarly, Interviewee E also emphasized the importance of meeting their own standards for their architectural designs, in addition to meeting the objective and achieving the goal within the limited budget set by the clients and the acceptance of clients. These personal standards provide architects with a sense of fulfillment and pride in their work, and motivate them to push their career and skills further down the road. The majority of architects interviewed expressed a strong intention to have their designs evaluated by other professionals, such as colleagues or architects from other organizations. Interviewee A expressed a desire to establish connections with people through her designs, as long as the evaluator has professional experience in the same field. Interviewee D also emphasized the importance of seeking local consultancies in order to obtain evaluations on factors such as climate conditions, cultural backgrounds, local aesthetics preferences, and building standards for potential adjustments and improvements to the design. And interviewee E said that he always seek for advices and feedback from his architects friends, previous tutors and teachers for potential refinements and improvements of the design every time before he submits the final draft to clients. And interviewee B believes that having external architectural design professionals to be part of the evaluation process will bring values to all the parties in the project. It is clear that architects recognize the value of receiving evaluations from other professionals, both within and outside of their organization as sometimes these evaluations can provide valuable insights and identify areas for improvement, ultimately contribution to the overall success of the project. In the interviews, it was found that the architects generally have a positive attitude towards assigning intellectual property with their designs, despite the lack of policies or initiatives that promote architects to assert ownership of their designs. They see this as a convenient way to distinguish their individual contributions in the entire design project and to safeguard their work against misuse or unauthorized usage. These architects recognize the value of their work and the importance of protecting their creative output. Therefore, they are open to the idea of assigning intellectual property rights to their designs because this ensures that they retain the legal ownership of their work and can use it as a means of promoting their professional reputation.Interviewee D expressed the importance of protecting intellectual property in architectural design, acknowledging that it is as crucial as safeguarding other knowledge or technical properties. However, Interviewee D also pointed out that over-protecting designs may hinder the creativity in architectural industry, as most new designs are inspired by older ones and architectural innovation thrives on the exchange or borrow of ideas. Therefore, finding a balance between protecting intellectual property and fostering creativity is essential for architects and the industry as a whole.

5.9 Systematic fulfillment analysis

In the systematic fulfillment level (Figure : 6), the architects shared their opinions on various topics, including their satisfaction level with the existing evaluation system and their expectations for future improvements. Surprisingly, none of the architects had gone through any literal architectural design evaluation processes in their professional careers, despite having done so during their education. This led to dissatisfaction with the existing systems among most of them. Interviewee A explained that her previous architectural firm put too much emphasis on profit, cost, and budget, instead of constructive feedback and more important things such as sustainability and human well-being. Interviewee E reported rarely seeing any requirements or attention given to circularity and sustainability in the architectural designs from his previous workplace. Interviewee D expressed dissatisfaction with the existing evaluation system, which he considers too static in terms of design and evaluation standards and he believes that the industry

standards should evolve with the changing human culture. However, a few interviewees felt satisfied with the existing systems, such as Interviewee C, who attributed her adaptability to responding to different evaluation requirements and processes. Interviewee B did not participate any evaluation process in her previous experience due to limited job responsibility, but she would love to and suggests more involvement from multiple parties of stakeholders, such as potential users, clients and architect teams. Overall, the insights gathered from the qualitative coding analysis of the interview data provide valuable information for understanding the current state and future direction of architectural design evaluation, which can inform the development of a more effective evaluation approach. Regarding the objective evaluation of architectural designs, as much as interviewed architects expressed their desire, their opinions are quiet different. Interviewee C and D both pointed out that design requirements and evaluation criteria vary greatly from project to project, making it difficult to achieve complete objective architectural design evaluation, despite its necessity from the perspective of architects. Interviewee E also believes that achieving the true objective value of architectural design is almost impossible because everyone has their own standards and preferences. Thus, it is challenging to achieve the ultimate objective value of any architectural design on both a personal and system level, where the industry standard is fragmented and constantly changing. However, although many architects have experienced bias and subjectivity in previous design processes, it is generally attributed to differences in cultural background, misinterpretation of project goals, and personal objectives, mentioned by interviewee A, D and E. Architects expressed a common desire for a future design evaluation approach or system that is more inclusive of sustainability, circularity, and contributions to the built environment globally. The architects believe that these aspects are crucial for better user experience, the longevity of the building, and sustainable development. Interviewee A and Interviewee D both noted that their previous employers and clients had missed the importance of sustainability and circularity, and this had resulted in a lack of consideration for the long-term benefits of the design. Interviewee C expressed that in addition to functional and sustainability considerations, the future evaluation system should also take into account the presentation and integration of the designed architecture into the project. She believes that the visual appearance and presentation of the design can greatly impact its success, and that the evaluation system should account for this aspect as well. This could include factors such as how the design fits into the surrounding environment, how it integrates with existing structures, and how it meets the aesthetic preferences of the target audience. By including these considerations in the evaluation process, architects can ensure that their designs not only meet functional and sustainability requirements but also satisfy the aesthetic needs of the users and stakeholders.

5.10 Summary of interview and literature review

As there is limited literature available about architectural design evaluation in a professional environment, the main findings from research are from interviews with experienced architects contacted through the researcher's personal network. The interviews provided valuable insights into the current state of design evaluation and the challenges that architects face in this process and answered one of the sub-research questions: What features should be expected by architects in a new design evaluation approach and what motivates architects to adopt it?'. The interview results revealed several problems encountered by architects in achieving personal fulfillment in their designs, such as the acceptance of their designs by stakeholders mostly depends on profit, budget, deadline rather than more important factors in the long run such as circularity and sustainability. Architects expressed a strong intention to have their designs evaluated by other professionals seeking for improvements, insights and connections, however, this phase is generally missing from the existing workflow of architects. In the system fulfillment level, architects expressed their dissatisfaction with the existing evaluation system. The architects believe that the current system lacks emphasis on constructive feedback, sustainability, and human well-being, which are more important factors that should be taken seriously in the long term, and their desire for a future design evaluation approach includes considerations for sustainability, circularity, and contributions to the built environment globally, as well as the presentation and integration of the designed architecture into the project. The architects believe that incorporating these factors into the evaluation process will result in improved user experience, building longevity, and sustainable development. In terms of design and evaluation standards, the current system is too static and does not account for the development of human culture and the architects desire a more inclusive and dynamic evaluation system that considers a variety of design elements and the surrounding environment. In conclusion, architects are faced with a variety of challenges, some of which include stakeholders placing a higher priority on profit, budget,

and deadlines than on long-term aspects such as circularity and sustainability, the absence of an effective evaluation phase, and insufficient intellectual property protection measures. Taking care of these problems is essential in order to improve the collaborative design efforts being made and obtain optimal results for all parties involved.

Chapter 6

Artifact Design and Development

The previous chapters have helped to establish a theoretical framework of this research through comprehensive literature review, interviews with architects and qualitative analysis on the interview results and identified the main research problems, requirements and expectations from architects about a comprehensive architectural design evaluation approach. Over this chapter, the insights gained from previous chapters will be turned into actions.

This chapter mainly focuses on the design and development of framework including framework conceptualization, design and development of core components of framework, which are membership systems powered by smart contract and a comprehensive evaluation system integrated from existing evaluation models.

The conceptualization will start with investigating existing DAOs, identifying the core technologies underpinning them, and selecting the most suitable blockchain platform to support the DAO framework. This analysis will bring clarity to the functional demands of DAOs, as seen from the perspective of different stakeholders. The selected blockchain platform will then provide the necessary foundation working environment for the design and development phase.

Then, the focus will shift towards the design and development phase, the first core component to be designed and developed is a membership system powered by smart contract which will be running completely autonomously. This exploration design and development will be governed by a set of principles and core functions that the system is expected to perform. It will further extend to the development of smart contracts that form the backbone of the system, and practical suggestions for implementing this system will be provided to ensure its successful deployment and integration.

The final part of this chapter will center around the integration of a comprehensive evaluation system, which caters to the demand and expectation from architects for extensive architectural design evaluations. Through this established evaluation system, architects could get comprehensive evaluation results while having the quality guarantee of results as it will be integrated with the membership system ensuring only reputable and qualified architects are able to evaluate others' designs. This union not only maintains the quality of the DAO's operations but also promotes a culture of continuous improvement within the organization. This strategic development engenders a DAO structure that is continually evolving, adaptive, and resilient.

6.1 Framework conceptualization

This section introduces the conceptualization of the DAO framework, which concists of 2 phases, the core function identification of DAO to facilitate effective architectural design evaluation, and selection of a blockchain so that a DAO and its smart contract can be deployed and operate on.

Core function identification

The findings from the qualitative analysis of the interview results revealed two key expectations among architects. The first is the desire for a platform where their designs can be evaluated by other professional or qualified architects. By exposing themselves to the critiques of other qualified professionals, they can receive valuable, constructive feedback which, in turn, can significantly enhance their design skills and expertise. The researcher believes this interaction also creates a knowledge-sharing platform, thereby fostering a community of continuous learning and professional growth among architects.

Additionally, interviewed architects also expressed the desire for a more comprehensive evaluation system. Interviewed architects generally expect a framework that extends beyond the basics of architectural design factors and project goals and incorporates a wider range of evaluation criteria. Aspects such as sustainability, circularity, cultural value, and aesthetics were highlighted as key parameters for evaluation. A more diverse evaluation criterion not only ensures a more objective evaluation result but also encourages architects to consider a wider range of factors in their designs, thus promoting more thoughtful, innovative, and impactful architectural designs.

With the expectation and insights from architects being summarized, the overall architecture of the framework can be defined as the figure illustrates (Figure 7), the core functions included in the DAO framework can be determined as follows:

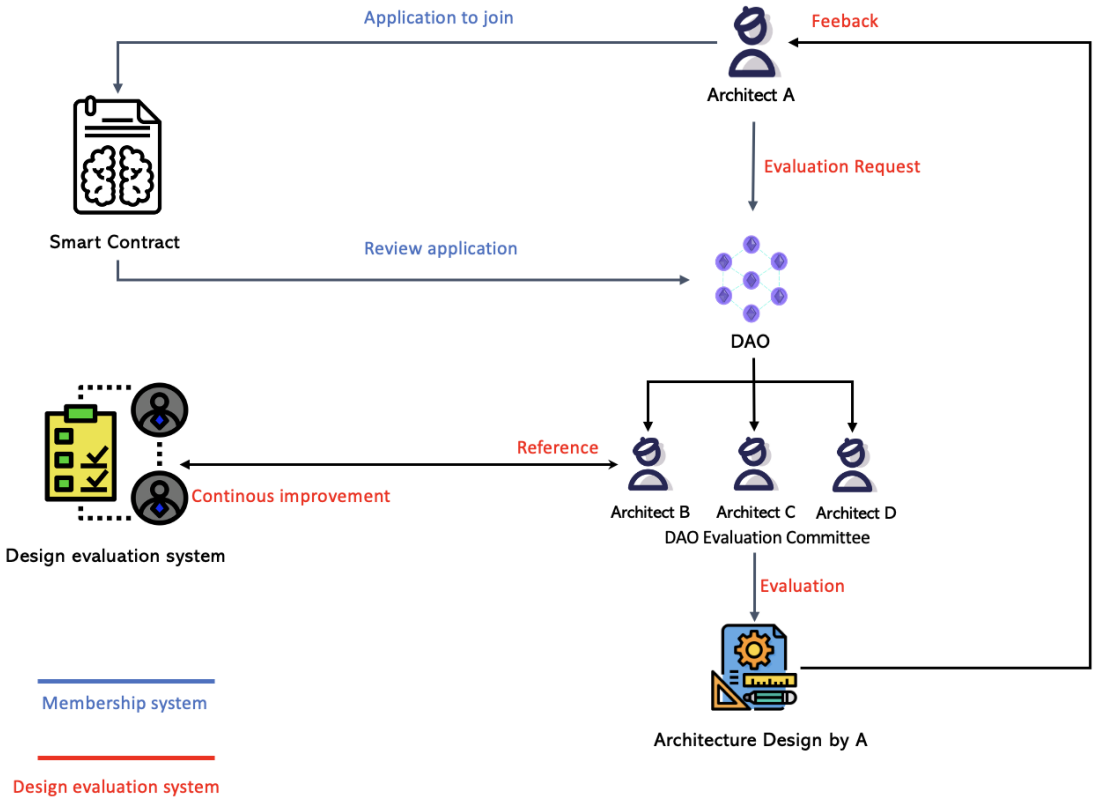


Figure 7: Conceptualized framework architecture

1. **A smart contract based membership system**
   In order to facilitate an effective and fair design evaluation process, the smart contract of membership system is implemented in a way that only allows qualified architects to join the DAO (labeled blue in the figure 7), by distributing the administration power to multiple members and requesting their permission to approve the application before the applicant is able to join. Meanwhile, the

smart contract is designed to run autonomously, by removing administrative power from contract creator and giving equal access to every DAO member, which signifies a move away from traditional hierarchical structures towards a more cooperative and democratic approach.

Moreover, the smart contract underlying this membership system also incorporates Non-Fungible Tokens (NFTs) to further enhance its functionality. In this DAO, NFTs serve as not only a representation of membership, but also a key to access and permission within the DAO, such as governance and operational activities, NFTs are stored in members' unique address in a decentralized approach which eliminates the needs to check the central database every time they need it.

2. **An extended and comprehensive design evaluation system**
The architects interviewed for this research expressed their expectation for a broader, more encompassing evaluation system within the DAO. An extended and comprehensive design evaluation system is thus proposed to meet this need (labeled red in the figure 7). This evaluation system is envisioned to incorporate the conventional criteria of architectural design and project objectives, incorporating a more diverse range of evaluation criteria. Essential elements such as sustainability, circularity, cultural value, and aesthetics have been underscored as crucial evaluative dimensions. The incorporation of such diverse criteria not only promises a more holistic and objective evaluation but also encourages architects to incorporate these varied aspects into their designs. Consequently, this stimulates the creation of more thoughtful, innovative, and impactful architectural designs. This comprehensive evaluation mechanism therefore forms a vital function within the DAO, contributing to the continual growth and development of its architectural community.

Blockchain selection

After the core functions have been defined, it is time to select a suitable blockchain to have the DAO built on. To build a foundational DAO framework, choosing an appropriate blockchain to build on is crucial. This choice is critical to ensure the seamless functioning and long-term sustainability of the DAO. After conducting a comprehensive evaluation of several leading blockchain options, **Ethereum** was chosen as the most optimal solution for the establishment of the DAO for its outstanding support to the key attributes that a DAO demands:

1. **Smart contract support**
Ethereum offers the most robust and proven smart contract tools and platform to implement secure voting, participation, and funding mechanisms within a DAO with thousands of live Decentralized Applications running on Ethereum, its smart contract instruments have the most advanced and resilient performance over all blockchains. On the other hand, the Ethereum network's strong focus on decentralization, security, and scalability ensures that DAOs built on it will benefit from a reliable infrastructure that can adapt to the ever-evolving demands of the blockchain landscape [8].

2. **Security**
Ethereum prioritizes security upgrades and enhancements along with auditing services and standards to protect DAO funds and operations and has a track record of securing billions in funds across its dApps and DeFi platforms. Since security is very important for a DAO, Ethereum's focus on security and its technical maturity gives people confidence to trust [8].

3. **Decentralization**
Both in technology and governance, Ethereum aims for decentralization which matches the distributed and democratic values of a DAO. There is no single group that controls Ethereum, and consensus from a broad community shapes all decisions. Unlike other blockchains that concentrate more influence into smaller sets of validators or developers, for an organization based on decentralization, Ethereum ensures no central points of failure or control [8].

4. **Scalability**
Ethereum continues improving scalability through layer 2 solutions and network upgrades to handle growing volumes from large DAOs and communities. While still developing, Ethereum's ecosystem already supports millions of users across thousands of dApps and offers the bandwidth required

with a roadmap to greater scale. For a populous DAO, Ethereum can provide enough throughput for all to participate freely [8].

5. **Governance**
   Ethereum furnishes partial on-chain governance models and frameworks to build upon and proposed upgrades also strengthen decentralised governance options. And with so many live DAOs, Ethereum simplifies reusing or learning from proven systems and has the opportunity to leverage existing governance procedures, saves time and trial and error in developing initial structures [8].

6. **Community**
   Ethereum's thriving community makes it the ideal choice for building a DAO. The ecosystem offers valuable resources and support, fostering innovation and streamlining DAO creation. By choosing Ethereum, builders can benefit from the collective wisdom and experience of its exceptional community, amplifying the utility and value of their Ethereum-based DAO [8].

In addition to the powerful attributes, Ethereum has also gained widespread recognition as a premier solution for establishing DAOs, consistently demonstrating its effectiveness and reliability over the years. Based on deepdao.io, the majority of top 100 DAOs in terms of assets under management and membership are hosted on Ethereum, moreover, it is home to prominent and successful DAOs, such as MakerDAO, Aave, and Uniswap, which have attracted large, active communities [16]. This proven track record, strong support for essential features, and massive adoption within the DAOs make Ethereum an excellent choice for constructing a DAO framework tailored to the needs of architectural design evaluation.

6.2 DAO membership system

The Membership System of the DAO in this research is an integral part of DAO infrastructure that leverages blockchain technology to facilitate the processes of joining, participating, and maintaining the DAO for architects. The membership system is built in a custom-designed smart contract written in Solidity, a high-level, statically typed programming language specifically designed for implementing smart contracts on the Ethereum blockchain platform and utilize the power of Ethereum's blockchain network to promote transparency, decentralization, and inclusivity while ensuring the quality and competence of the members. The primary motivation behind implementing this membership system is to foster a DAO that comprises only qualified architects, ensuring that evaluations and peer reviews maintain high professional standards. This approach is instrumental in building trust, establishing credibility, and promoting valuable contributions within the DAO. And further motivations of the membership system implementation will be discussed the in the following section.

6.2.1 Design motivations

- **Decentralized Access Management:** The inherent decentralization in DAOs resonates with the core principles of smart contracts. A smart contract-based membership system ensures no single authority controls access rights within the DAO, creating an fair and democratic platform. Here, the smart contract governs membership rights, offering equal access to every member, thereby fostering fairness and precluding potential abuse of power [8].
- **Autonomous Operation:** Smart contracts' ability to operate autonomously once deployed eliminates the need for continual oversight, ensuring the DAO's seamless operation. This eliminates potential inefficiencies often associated with traditional, centrally managed systems [70].
- **Transparency:** In a smart contract-based membership system, all transactions, including membership required ones, are publicly recorded on the blockchain, visible to all participants. This transparency amplifies trust among members, making access and permissions within the DAO transparent and any attempt to manipulate membership records easily detectable [8].
- **Immutability:** Blockchain's immutability ensures the permanence of recorded transactions. This feature is crucial for membership records, where an unchangeable record of DAO participation is key.

- **NFTs for Membership:** Using NFTs to symbolize membership within the DAO is a progressive and effective approach. One could argue that keeping the membership list within the smart contract is a viable method, but this can introduce complexities such as handling member additions and removals, and constantly updating the contract. However, by assigning a unique NFT to each member, the process becomes simpler and more efficient. The unique nature of each NFT ensures secure and easily verifiable representation of identity. This simplifies the process of verifying a member's status, as the possession of an NFT can be swiftly checked via blockchain transactions, thus, eliminating any need for maintaining and constantly updating a separate list. Furthermore, NFTs can also introduce opportunities for members to have differentiated access levels or privileges based on different types of NFTs, creating a more dynamic and adaptable membership system.

6.2.2 Core functions desgign

Based on the main functionalities identified from previous sections and expectation from architects, the main functions which will be implemented in the smart contract of membership system can be defined as follows:

Application for joining the DAO
In order to become a DAO member, any architect with the necessary qualifications can start an application to join the DAO through a smart contract (Figure 8). To democratize the process, the smart contract sends this application as transactions to three different DAO members. This number, while arbitrary, has been chosen for specific reasons. First, it strikes a balance between achieving objectivity in the decision-making process and maintaining efficiency. With too few members involved, the decision may be biased or subjective. On the other hand, having too many members could slow down the process and potentially lead to decision paralysis. Three members can provide diverse perspectives while still allowing for efficient decision-making. Second, it also mitigates the risk of system abuse, such as favoritism or nepotism, by requiring a unanimous decision from all three members for membership approval. This design choice aligns with the DAO's decentralization principles, encouraging broad and equal

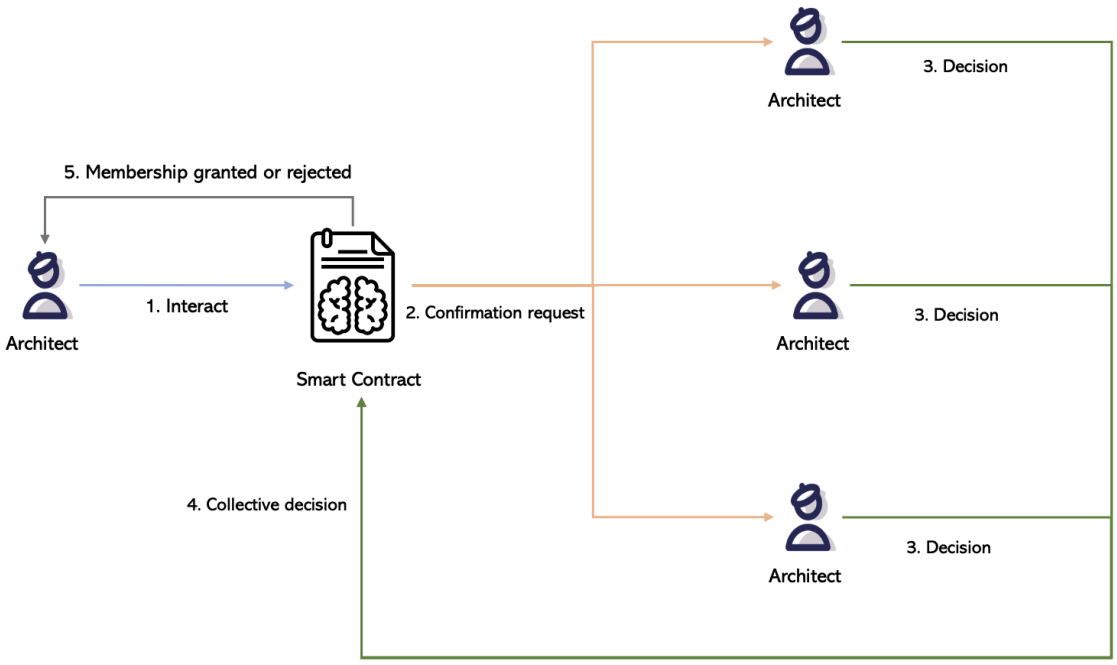


Figure 8: Application to join the DAO

participation in its management.

Membership removal
The membership system of the DAO incorporates a feature that enables members to initiate the removal

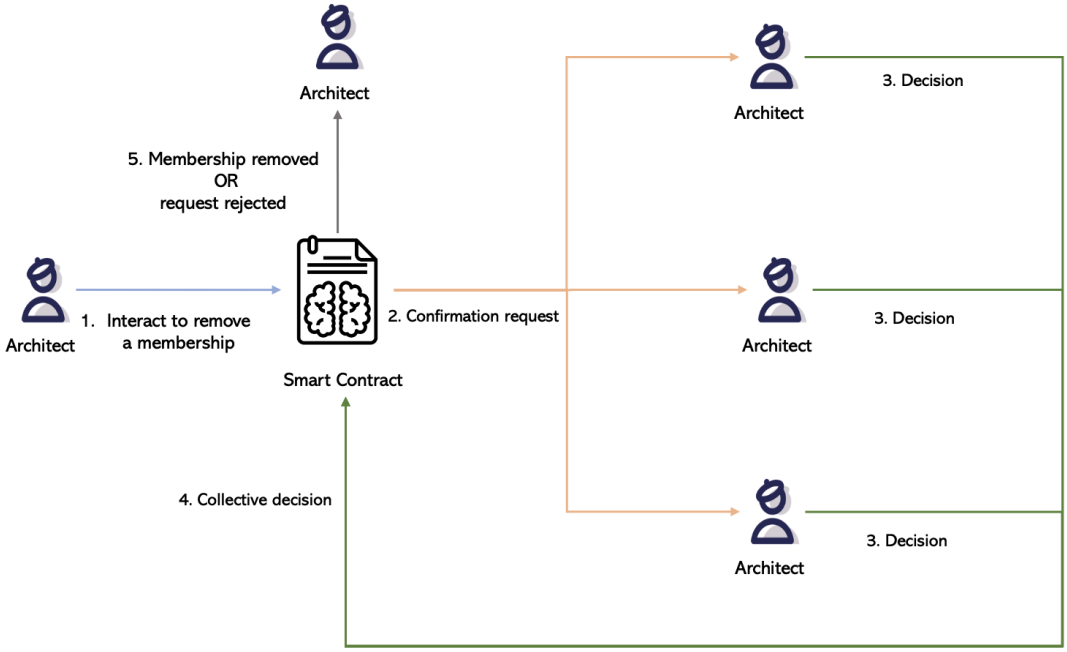


Figure 9: Application to remove a member

of other members who have been implicated in misconduct or no longer fulfill membership requisites (Figure 9). This removal process can be commenced through a smart contract, which subsequently informs three randomly chosen DAO members of the removal proposition. The selection of 'three' DAO members for this process is similar to the application process. It ensures a balanced decision-making process that incorporates diverse perspectives but still allows for swift action. Also, it prevents any single member from having the unilateral power to remove others, which could potentially be misused. Agreement from all three members is obligatory for the removal of the implicated member. This mechanism safeguards the DAO's integrity and maintains high conduct standards.

Membership rating system The DAO membership system incorporates a critical feature: a rating system (Figure 10). This system, embedded as a data structure within the smart contract, signifies a member's experience and reliability in evaluating architectural designs. Each completed review by a DAO member results in an increment of one point in their rating. This rating mechanism aims to incentivize members to provide high-quality reviews, as it directly influences their individual ratings. Consequently, this encourages a culture of excellence and fine assessment within the DAO. Moreover, this rating system provides architects with a reference point when seeking evaluators for their designs. It empowers them with the ability to choose evaluators with proven records of providing valuable and high-quality feedback, further enhancing the effectiveness of the evaluation process within the DAO.

Architectural design evaluation system
The essential function of design evaluation system (Figure 11) is allowing architects to request design evaluation from other architects in the DAO and get feedback from them. The design evaluation will be conducted in 2 phases in 2 different environment, on-chain and off-chain. The on-chain part of design evaluation involves architects requesting evaluation through smart contract (phase 1), which afterwards forward the request to DAO member, for proving the authenticity and transparency of this transaction and activity. After that, the real design evaluation or other interaction can happen 'off-chain' through in-

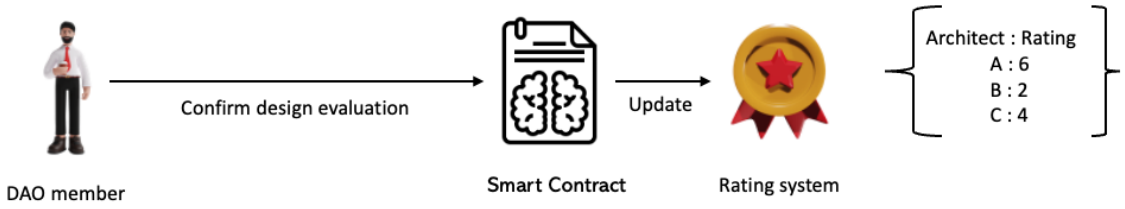


Figure 10: Membership rating system

person and online conversation (phase 2). For example, after the DAO member receives to-be-evaluated designs from architects, he or she could carry out the design evaluation following the guideline or evaluation criteria defined by DAO and give feedback to architects in person or through other media like emails or phone call.

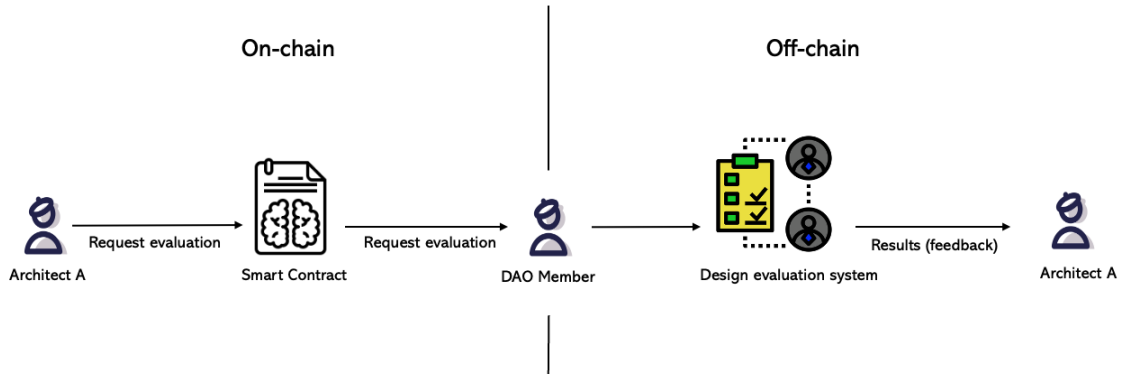


Figure 11: Design evaluation system

6.2.3 Smart contract development

After the core functions of the membership system of the DAO have been defined, this section will introduce the development of smart contracts. The smart contract developed for the DAO will handle most operational activities autonomously for the DAO including membership enrollment and removal and evaluation request processing. The OpenZeppelin [53] smart contract library provides additional utilities to the contract's ERC721 standard architecture to prevent reinventing the wheels. The motivations behind the major design and contract functions implementation are discussed below:

Contract declaration and import

The membership contract, facilitated by non-fungible tokens (NFTs) is utilizing several smart contract templates from the OpenZeppelin library (Figure 12), it is designed to govern membership, evaluate new membership applications, and process removal requests. Key elements include ERC721URIStorage for unique membership representation, Address for safe handling of Ethereum addresses, Counters for secure incrementing/decrementing operations, and Ownable to restrict certain operations to the contract owner. Each DAO member is symbolized by an NFT token, offering clear ownership and membership status within the DAO.

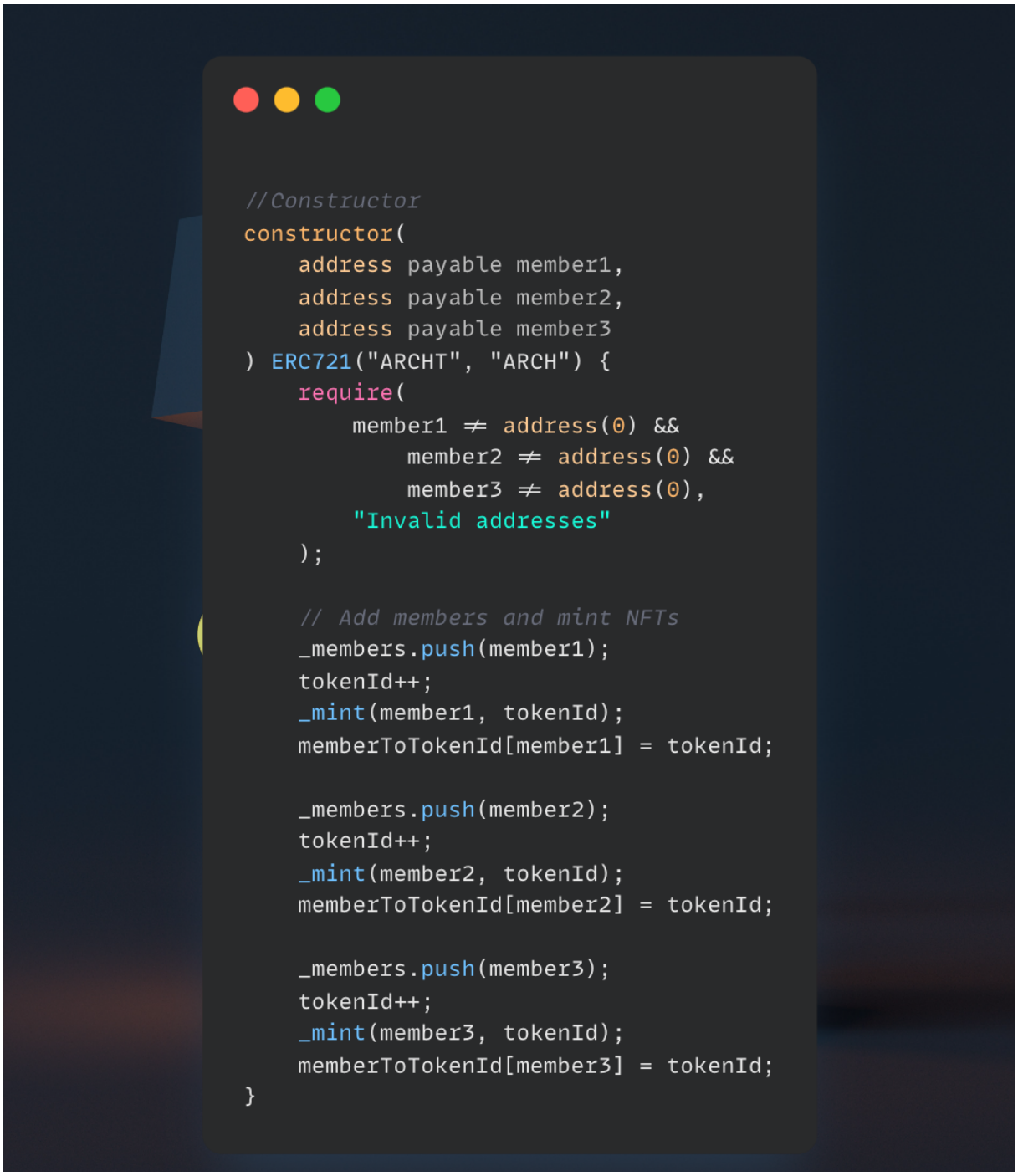
Figure 12: contract declaration and import

Creation of DAO

The constructor function (Figure 13) in this code initiates the DAO contract, establishing its initial state by creating and assigning three members. The function takes three addresses as parameters (member1, member2, member3), all of which represent the founding members of the DAO. It checks that these addresses are not null to avoid common smart contract deployment errors. Upon verification, these addresses are added as members of the DAO, and each member's address is mapped to a unique NFT (Non-Fungible Token). Subsequently, a unique NFT is minted for each member, offering a definitive proof of DAO membership. The creation of NFTs for membership is advantageous when members need to substantiate their DAO affiliation in external environments. However, it's crucial to note that these membership NFTs are non-transferable, ensuring the integrity of the membership structure. The three initial members establish a minimal committee for the DAO's decision-making processes such as new member application and design evaluation, fostering a balance between diverse perspectives and ease of consensus. This design decision bolsters the democratic functioning of the DAO, affirming equitable decision-making processes from its inception. Fundamentally, this constructor function lays a solid groundwork for a democratic and decentralized DAO, with non-transferable tokenized membership forming its core.

Membership enrollment

The **applyToJoin** function (figure 14) is designed to allow users to apply for membership in a DAO. It begins by checking if there are at least three members in the DAO, ensuring it is operational and has a decision-making body and diversity of opinions during the evaluation of the application. Then, it creates an application using the applicant's details: name, wallet address, and portfolio URL, which are saved in a struct and mapped to the applicant's address. Following that, it randomly selects three DAO members to evaluate the application. These members are chosen using a pseudo-random number generator and are removed from a temporary array after being selected to prevent duplicate selections. This ensures fairness and avoids any single member from having undue influence over the application process. The selected evaluators are added to an evaluators list in the application struct, where they are expected to review and vote on the application. The motivation behind this design choice is to ensure a decentralized, fair, and transparent decision-making process for admitting new members into the DAO.



```
//Constructor
constructor(
    address payable member1,
    address payable member2,
    address payable member3
) ERC721("ARCHT", "ARCH") {
    require(
        member1 != address(0) &&
            member2 != address(0) &&
            member3 != address(0),
        "Invalid addresses"
    );

    // Add members and mint NFTs
    _members.push(member1);
    tokenId++;
    _mint(member1, tokenId);
    memberToTokenId[member1] = tokenId;

    _members.push(member2);
    tokenId++;
    _mint(member2, tokenId);
    memberToTokenId[member2] = tokenId;

    _members.push(member3);
    tokenId++;
    _mint(member3, tokenId);
    memberToTokenId[member3] = tokenId;
}
```

Figure 13: Initialization of DAO contract

The **confirmApplication** function(Figure 37) is meant to be called by existing members, acting as judges, to approve an applicant. The function first checks that the member calling the function has not already confirmed the application (preventing duplicate confirmations). Then, it sets the confirmation from this member to true and increments the total confirmation count for this applicant. This design choice encourages member participation and achieves consensus through majority approval, thereby strengthening the overall decision-making process within the DAO.

The **rejectApplication** function (Figure 37) allows a member to reject an application outright. The function checks that the application has not already been confirmed or rejected by the caller, avoiding conflict or confusion. If not, it then deletes the application entirely from the mapping, effectively rejecting

ArchtDAO.sol

```
function applyToJoin(string memory name, address walletAddress, string memory portfolioUrl) public payable {
    require(_members.length >= 3, "No enough addresses");
    require(
        address(this).balance >= msg.value,
        "No enough Ether in contract"
    );

    Application storage application = applications[msg.sender];
    application.name = name;
    application.walletAddress = walletAddress;
    application.portfolioUrl = portfolioUrl;

    address payable[] memory tempAddresses = _members;
    for (uint i = 0; i < 3; i++) {
        uint index = genRandomNum() % tempAddresses.length;

        // Assign the member to confirm the application
        applications[msg.sender].confirmations[
            tempAddresses[index]
        ] = false;

        // Add the address to the evaluators array
        application.judges.push(tempAddresses[index]);

        // Remove the member from the temporary array
        tempAddresses[index] = tempAddresses[tempAddresses.length - 1];
        assembly {
            mstore(tempAddresses, sub(mload(tempAddresses), 1))
        }
    }
}
```

Figure 14: Function:apply to join

the applicant. This is a potent tool, giving members the power to block entries that don't meet DAO's standards, which can be crucial in maintaining the DAO's purpose, integrity, and values.

ArchtDAO.sol

```
function confirmApplication(address applicant) public {
    require(
        applications[applicant].confirmations[msg.sender] == false,
        "Already confirmed"
    );

    // Confirm the application
    applications[applicant].confirmations[msg.sender] = true;
    applications[applicant].confirmationCount++;

    // Check if the confirmation count is 3 or more
    if (applications[applicant].confirmationCount >= 3) {
        // Add the applicant as a member of the DAO
        _members.push(payable(applicant));
        tokenId++;
        _mint(applicant, tokenId);
        _totalSupply.increment();
        memberToTokenId[applicant] = tokenId;

        // Remove the application from the mapping
        delete applications[applicant];
    }
}
```

Figure 15: Function:Application confirmation or rejection

The **joinDAO** function (Figure 16) is designed to allow an applicant to join the DAO once his application has been approved by selected three members. The require statement ensures that this happens. Upon joining, the new member is added to the members array and an NFT (Non-Fungible Token) is minted for them using the mint function. This NFT serves as a membership token, with the tokenId acting as the unique identifier for the member within the DAO. The use of NFTs as membership tokens has several advantages:

1. Uniqueness: Each NFT is unique, which means each membership token is unique. This can help in easily identifying and verifying members.

2. Interoperability: NFTs are based on a standard (ERC721) that is widely recognized and supported across various platforms. This makes it possible for the membership token to be integrated with other platforms and services.

3. Proof of Ownership: NFTs provide verifiable proof of ownership. This is especially useful in a DAO where it's crucial to ensure that only valid members have voting rights or access to specific features.

4. Immutability: NFTs are stored on the blockchain, making them tamper-proof. Once issued, the membership cannot be altered or forged.

```
function joinDAO() public {
    require(
        applications[msg.sender].confirmationCount ⩾ 3,
        "Application not approved yet"
    );

    _members.push(payable(msg.sender));
    tokenId++;
    _mint(msg.sender, tokenId);
    _totalSupply.increment();
    memberToTokenId[msg.sender] = tokenId;
    delete applications[msg.sender];
}
```

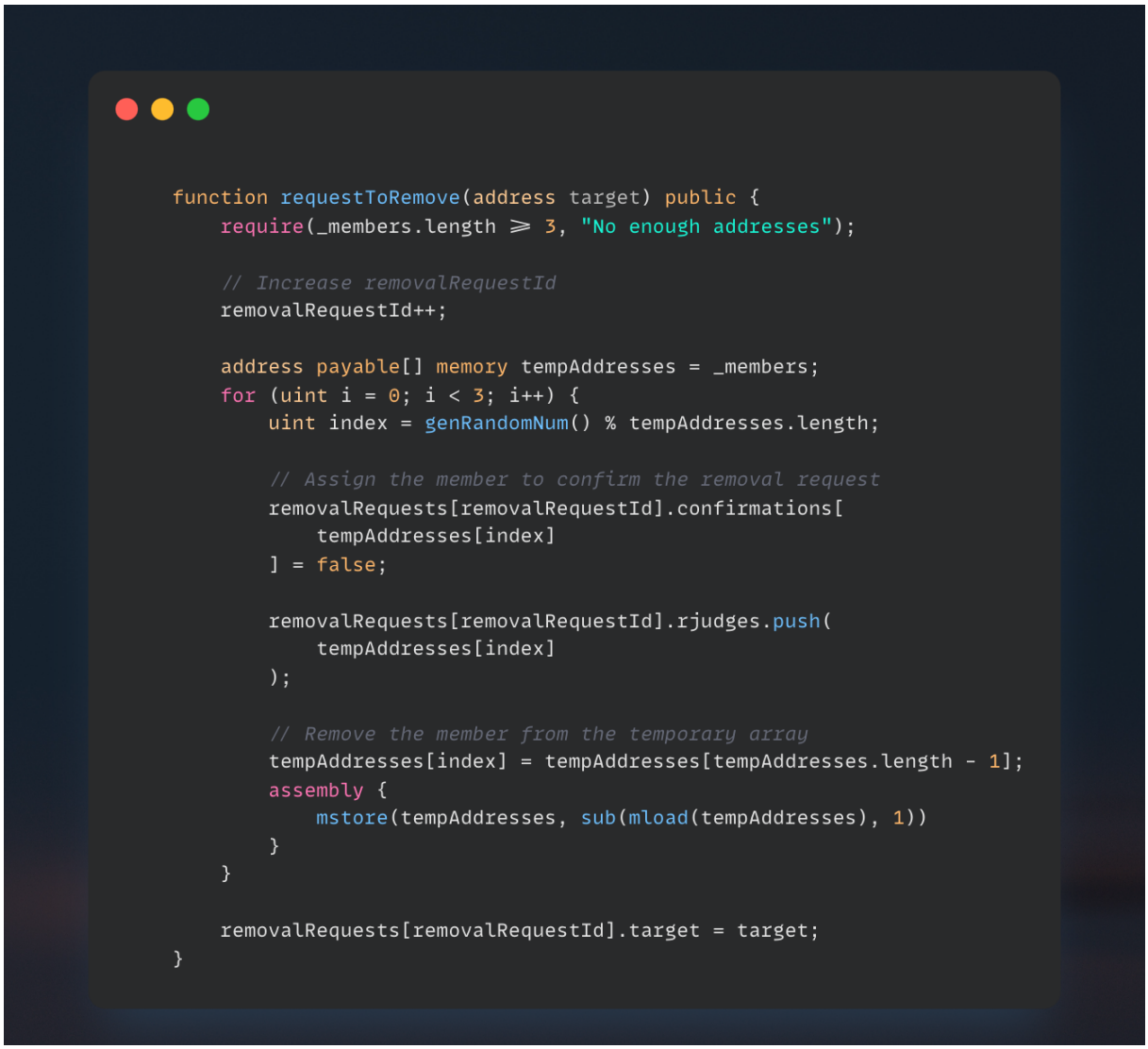
Figure 16: Function:Function to join the DAO

Membership removal

The **requestToRemove** function (Figure 17) is part of the governance of the DAO this contract is implementing. The function's design allows any member of the DAO to start a proposal for removing another member. The key components of this function are as follows:

- The function checks if the DAO has at least 3 members (require(_members.length ¿= 3, "No enough addresses");). This is likely to ensure that the DAO has a minimum amount of decentralization before any removals can be proposed.
- The function generates a new removal request ID (**removalRequestId**++;), which is used to track and manage the proposal in the **removalRequests** mapping.
- The function selects three random DAO members to serve as evaluators for the removal proposal. It does so by generating a random number (uint index = genRandomNum() % tempAddresses.length;) and assigning that member to confirm the removal request. This random selection ensures fairness and impartiality in the review of the removal request.
- The function removes the chosen members from the temporary array to avoid selecting the same member more than once.
- Finally, the function stores the target of the removal request in the **removalRequests** mapping.

The main motivation behind this design choice is to ensure a fair, impartial, and decentralized process for the removal of a member from the DAO. This function makes sure that not just one individual has the power to remove members, thus maintaining the essence of decentralization. The use of randomness in selecting the members for evaluating the removal request is a mechanism to prevent bias in the decision-making process.



```
function requestToRemove(address target) public {
    require(_members.length ⩾ 3, "No enough addresses");

    // Increase removalRequestId
    removalRequestId++;

    address payable[] memory tempAddresses = _members;
    for (uint i = 0; i < 3; i++) {
        uint index = genRandomNum() % tempAddresses.length;

        // Assign the member to confirm the removal request
        removalRequests[removalRequestId].confirmations[
            tempAddresses[index]
        ] = false;

        removalRequests[removalRequestId].rjudges.push(
            tempAddresses[index]
        );

        // Remove the member from the temporary array
        tempAddresses[index] = tempAddresses[tempAddresses.length - 1];
        assembly {
            mstore(tempAddresses, sub(mload(tempAddresses), 1))
        }
    }

    removalRequests[removalRequestId].target = target;
}
```

Figure 17: Function:Membership removal

The **confirmRemoval** function (Figure 18) allows members, acting as evaluators, to confirm the removal of a DAO member. The process begins with a validation of the removal request ID, preventing misuse of the function. It then checks if the evaluator has already confirmed the removal request, preventing duplicate confirmations. If not, the confirmation is registered and the count increases. If the removal request receives at least three confirmations, the target member is identified and removed from the member list, the associated NFT is burned, the total NFT supply is reduced, and the membership mapping is cleared. This design choice ensures a decentralized, consensus-based removal process that maintains DAO integrity. Requiring multiple confirmations prevents unilateral member removal, while burning the NFT helps retain the uniqueness of each membership.

Evaluation request and rating system

The **applyForEvaluation** function(Figure 19) enables a user to request an evaluation by a set of chosen evaluators. The maximum number of evaluators is set to 3, which is a design choice to balance between decision accuracy and efficiency. Having multiple evaluators provides a more objective evaluation process as it is less likely to be biased, which supports fair decision making. However, allowing too many evaluators might cause inefficiency in the process as it takes longer for all evaluators to cast their decisions and having exactly the number of 3 evaluators is not determined for this case and future implementation can modify

```
function confirmRemoval(uint requestId) public {
    require(requestId == removalRequestId, "Invalid request id");
    RemovalRequest storage request = removalRequests[requestId];
    require(
        request.confirmations[msg.sender] == false,
        "Already confirmed"
    );

    // Confirm the removal
    request.confirmations[msg.sender] = true;
    request.confirmationCount++;

    if (request.confirmationCount >= 3) {
        // If 3 or more members confirmed the removal, remove the member
        for (uint i = 0; i < _members.length; i++) {
            if (_members[i] == request.target) {
                _members[i] = _members[_members.length - 1];
                _members.pop();
                break;
            }
        }

        // Burn the NFT associated with the removed member
        _burn(memberToTokenId[request.target]);
        _totalSupply.decrement();
        delete memberToTokenId[request.target];
    }
}
```

Figure 18: Function:Membership removal confirmation

this number to adapt upcoming situations. The function first checks if the number of evaluators is valid, then increments the **evaluationId**, and finally, records the evaluation request details in the evaluations mapping. This design enforces the restrictions on evaluator count and ensures each evaluation request is properly recorded and retrievable.

Evaluation request and rating system

The **confirmEvaluation** function (Figure 20) allows a designated evaluator to confirm the completion of their evaluation. First, it checks whether the given evaluation ID is valid (i.e., it's less than or equal to the current highest evaluation ID). The design choice to use a numerical, incrementing ID for evaluations simplifies the process of tracking and validating evaluations and facilitates a linear and chronological record of all evaluation activities.

Next, it verifies if the caller of the function (i.e., msg.sender) is an evaluator for this particular evaluation, to ensure that only assigned evaluators can confirm an evaluation. This loop iteration and Boolean check is necessary to maintain the integrity and trustworthiness of the evaluation process. Then, it confirms that the evaluator has not already confirmed the evaluation, thereby ensuring that an evaluator can only confirm an evaluation once. This design choice again preserves the validity and fairness of the evaluation process.

Upon confirming the evaluation, the function updates the confirmations mapping and increments the

```
function applyForEvaluation(address[] memory evaluators) public payable {
    require(evaluators.length <= 3, "Too many evaluators");

    // Increase evaluationId
    evaluationId++;

    // Store evaluation request
    Evaluation storage evaluation = evaluations[evaluationId];
    evaluation.requestor = msg.sender;
    evaluation.evaluators = evaluators;
}
```

Figure 19: Function:Apply for evaluation

```
function confirmEvaluation(uint _evaluationId) public {
    require(_evaluationId <= evaluationId, "Invalid evaluation id");
    Evaluation storage evaluation = evaluations[_evaluationId];
    bool isEvaluator = false;

    for (uint i = 0; i < evaluation.evaluators.length; i++) {
        if (evaluation.evaluators[i] == msg.sender) {
            isEvaluator = true;
            break;
        }
    }

    require(isEvaluator, "Not an evaluator");
    require(
        evaluation.confirmations[msg.sender] == false,
        "Already confirmed"
    );

    // Confirm the evaluation
    evaluation.confirmations[msg.sender] = true;
    evaluation.confirmationCount++;

    // Increase rating for evaluator
    ratings[msg.sender]++;
}
```

Figure 20: Function: Confirm evaluation

confirmationCount for the evaluation, thereby keeping track of how many evaluators have confirmed the evaluation.

Finally, it increases the ratings of the evaluator, which can serve as a reward mechanism to encourage evaluators to perform their role. This design choice of tying evaluator rewards to the number of evaluations completed can incentivize participation in the evaluation process and promote active engagement within the DAO. The specific implementation of the ratings system would depend on the larger design of the DAO, but the general principle is to create incentives aligned with the DAO's objectives.

On the other hand, the rating system serves as a trust indicator, ensuring the quality and reliability of evaluators within the DAO. A higher rating suggests more experience and credibility, thus architects can have greater confidence in the feedback they receive. It also promotes quality assurance, as evaluators strive to provide detailed and thoughtful evaluations to maintain or improve their ratings.

Other functions

Figure 21: Function:Renounce ownership of contract

The **renounceOwnership** function(Figure 21) is designed to allow the owner of the DAO to give up their ownership of smart contract and allow the smart contract and the DAO can run autonomously. This function is implemented adheres to the decentralized principles of a DAO, allowing for shared ownership and equal governance, however, it is still optional for implementation while considering upcoming uncertainties like future upgrades of smart contract which needs someone to take the ownership of the smart contract to make that happen, in this case, the function is not necessary to be implemented.

6.3 Design evaluation system

The architectural design evaluation system developed in this research serves as a core component of the whole framework. The evaluation system is designed with the explicit aim of offering an extensible evaluation platform for architects, acknowledging a range of factors that influence the design process and contribute to the quality and value of architectural outcomes. The criteria included in this evaluation system are inspired by extensive interviews with architects and reflect critical dimensions of architectural practice and thought: sustainability, circularity, technology, human-centric design, aesthetics, and cultural considerations. Each of these elements is significant in its own right, and together they form a comprehensive approach to architectural evaluation. To ensure the evaluation system remains current and adaptable to evolving architectural practices, it draws upon the latest research and frameworks for

assessment. In turn, it aims not just to evaluate, but also to stimulate the continual development and advancement within the architectural field. Each evaluation criterion is accompanied by a set of referencing frameworks, providing evaluators with functioning and cutting-edge resources to inform their evaluation.

The motivation driving this evaluation system extends beyond an extensive architectural evaluation. It is also designed to inspire architects within the DAO to exchange knowledge, explore new dimensions in the architectural field, and refine their craft continually. Moreover, it aims to stimulate architectural innovation, pushing the boundaries of what is achievable and envisaged within the field. In this way, the evaluation system serves as a dynamic tool for encouraging creative excellence, fostering shared learning, and promoting continual advancement within the architectural DAO. The integration of these criteria within the framework builds upon the foundations of various available frameworks dedicated to design evaluation, ensuring a comprehensive and informed approach to architectural design evaluation.

The evaluation system consists of 3 modules, sustainability, circularity, and multi-level evaluation encompassing technology, human factors, aesthetics, and culture. These modules have been adapted and integrated from established evaluation models present in existing research, underlining the system's robustness. The motivation behind this structure is to provide a comprehensive, balanced, and objective evaluation of architectural designs, while promoting sustainable and culturally sensitive design practices.

6.3.1 Sustainability

The first model for evaluating building sustainability utilized in this research was adapted from Markelj et al.'s 2014 research [43]. This model (Figure 22) was selected due to its encompassing approach to assessing sustainability in architecture, which embraces various dimensions such as energy, environmental, and socio-economic factors. This approach ensures that architectural designs are evaluated against a set of criteria that fully embody the principles of sustainable design.

1. Energy Factors: The model assesses energy performance through several key metrics, including energy consumption and the potential for renewable energy use. Architectural designs in our evaluation system are reviewed for their energy efficiency and potential for integration of renewable energy sources, reflecting this aspect of the model.
2. Environmental Factors: Environmental considerations involve the use of sustainable materials, water management, waste management, and the impact on biodiversity. The architectural designs evaluated are scrutinized for their utilization of sustainable materials, water and waste management strategies, and potential impact on local biodiversity.
3. Socio-Economic Factors: Lastly, the socio-economic aspect of the model is reflected in the assessment of aspects such as accessibility, adaptability, and affordability of the architectural designs. The evaluation system assesses designs for their potential to fulfill these criteria, promoting architecture that benefits wider society and contributes to sustainable development goals.

In Markelj's understanding, sustainability is more than a simple checklist; it demands a comprehensive understanding of the complex relationships between various factors, therefore, the model crafted by them embraces this idea by acknowledging the interconnected nature of sustainability criteria. The architectural design evaluation system formulated in this research reflects this comprehension. It recognizes the complex web of elements that define sustainable design and advocates for an all-encompassing evaluation approach that is detailed, sensitive to changes, and responsive to the fluid nature of architectural design and its broader impacts. Aligning with a well-acknowledged model of sustainability evaluation not only bolsters the trustworthiness of the evaluation system but also aids in a more thorough and balanced exploration of sustainability in architectural designs.

An alternative evaluation model that can be integrated into the evaluation system is 'BREEAM-NL New Construction' , a sustainability certification method used for evaluating the sustainability performance of a real estate object, which is widely used all over the world, especially in Netherlands.BREEAM, which stands for Building Research Establishment Environmental Assessment Method, is a leading and globally recognized method for measuring and certifying the sustainability performance of buildings. This

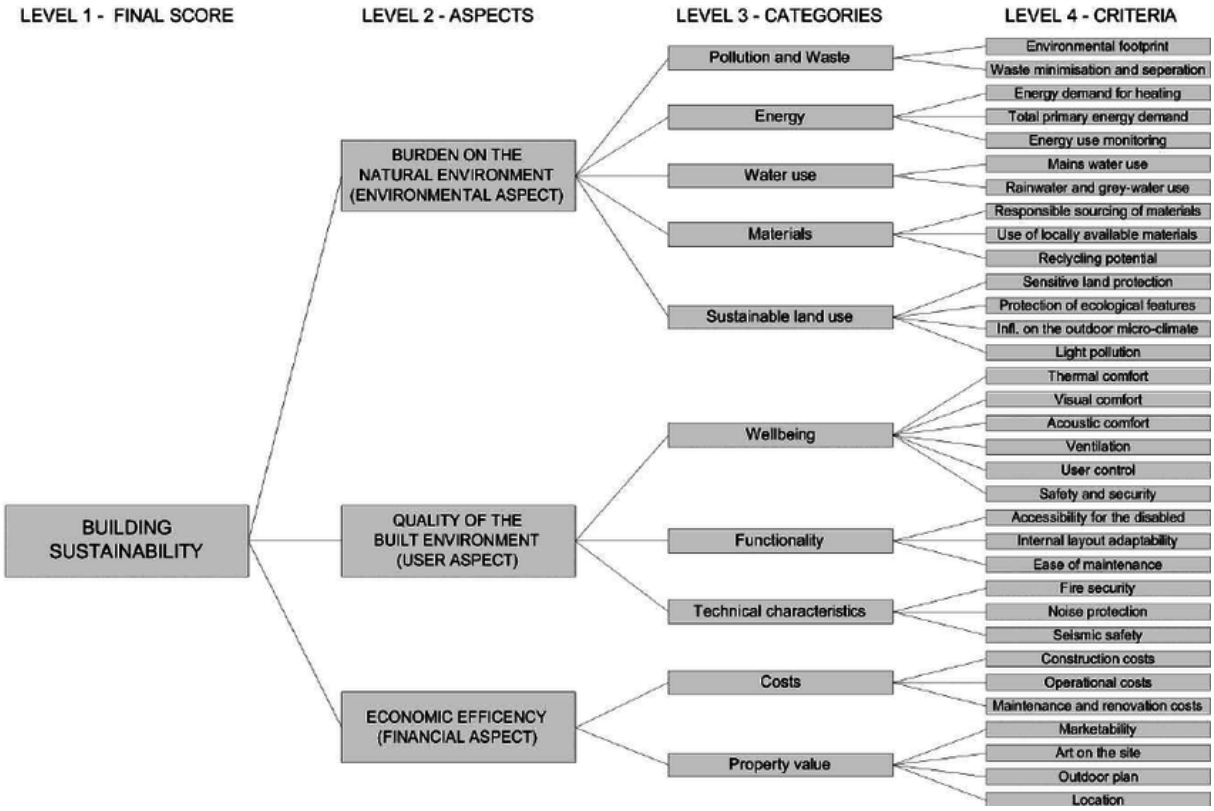


Figure 22: Architectural design sustainability evaluation model (Markelj et al., 2014)

method sets the standard for best practice in sustainable design, serving as a benchmark to determine the sustainability level of architecture buildings [24] .

The objectives of BREEAM includes:

- Create sustainable buildings with minimal environmental impact, enable the distinction of buildings according to sustainability, provide a credible certification for sustainable buildings, and stimulate the demand and supply of sustainable buildings [24].
- Provide market recognition of buildings with low environmental impact, ensure that sustainable best practices are incorporated into buildings, set standards and criteria that exceed legal requirements, challenge the market to provide innovative solutions that optimize the sustainability performance of buildings, and increase the awareness of building owners, users, developers, and managers about the benefits of buildings with limited environmental impact [24].

BREEAM-NL is a version of BREEAM adapted for the Netherlands by the Dutch Green Building Council (DGBC), has been the certification method for a sustainable built environment since 2009.The BREEAM-NL New Construction 2020, in particular, is intended for assessing the environmental impact of new buildings during the design and construction phase.

The final BREEAM qualification, ranging from 'Pass' to 'Outstanding' can be calculated by the tools provided by DGBC (Figure 23) which relies on data provided by applicants. This calculation process involves steps such as defining the project's scope, determining the points scored per function and category, and establishing the percentage of points scored per function for each category based on the highest achievable points. These steps eventually leads to the final qualification. To achieve an 'Outstanding' BREEAM-NL qualification, the score of evaluation must meet the following requirements: the BREEAM-NL score must be greater than 85%, all mandatory credits and minimum requirements must be met, and a case study must be provided according to the guidelines. There are 9 categories included in the evaluation system by BREEAM-NL, including management, water, materials, health, waste, energy, pollution,

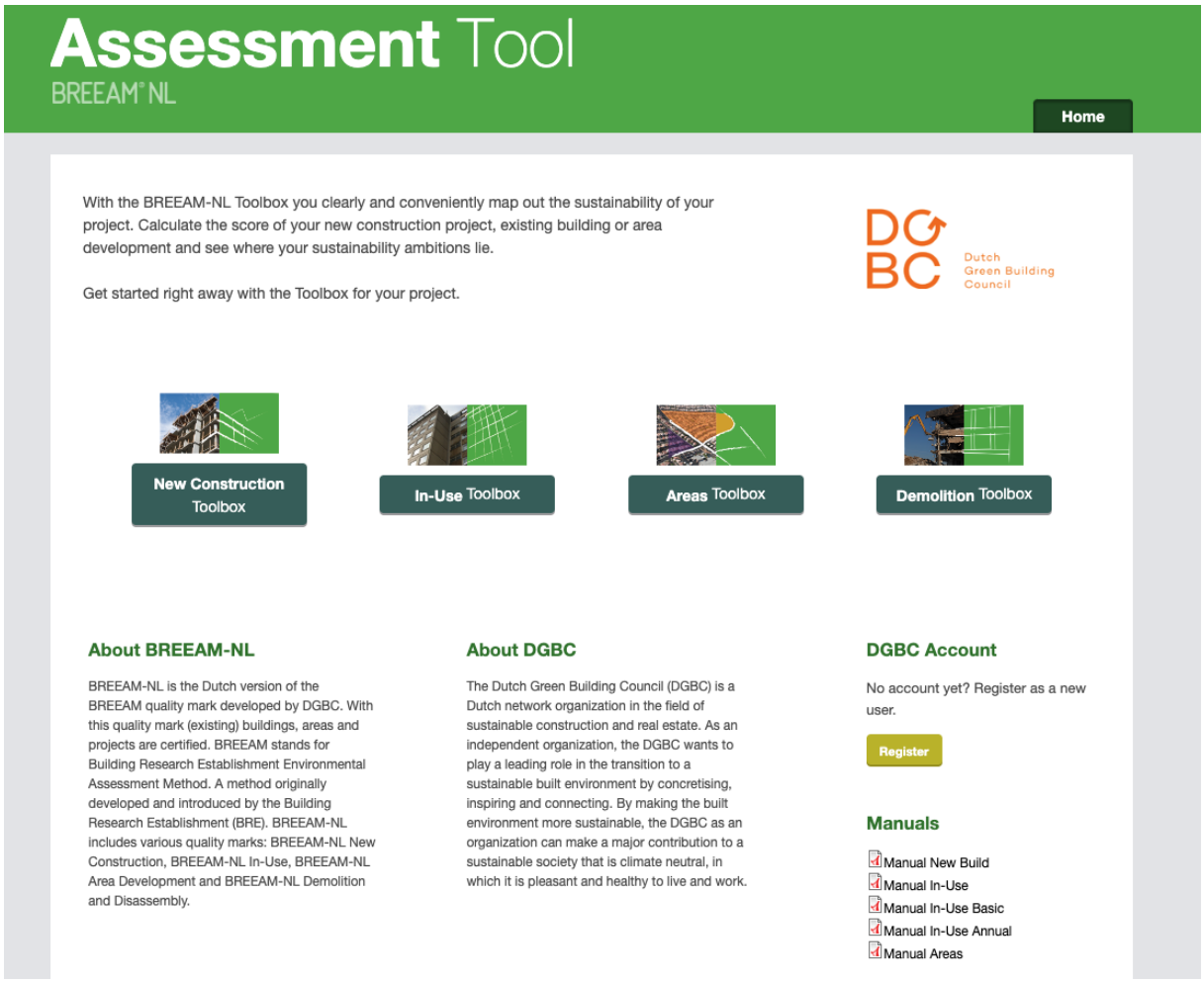


Figure 23: DGBC assessment tool

landuse and ecology and transportation (Figure 24). More information can be found in the guideline of certification by BREEAM-NL (`https://richtlijn.breeam.nl/1-inleiding-383`).

In integrating BREEAM into the DAO's evaluation system, evaluators can leverage the BREEAM evaluation model as a reference during their assessment process. This would mean that evaluation within the DAO would take into account the wide range of sustainability metrics included in the BREEAM system, thus ensuring a comprehensive evaluation of the sustainability aspects of the architectural designs. Furthermore, the utilization of BREEAM in DAO's system can also potentially encourage architects to consciously incorporate sustainable practices into their designs, driving the architectural field towards a more environmentally friendly future.

6.3.2 Circularity

The architectural design circularity evaluation model in this research draws its foundational concepts from the criteria established by Attia and Al-Obaidy [4]. This model considers four main elements that greatly influence strategic decisions in circular building design or renovation. The criteria selection is rooted in comprehensive literature reviews, reclamation audits, and structured discussions with building waste management contractors.

1. Carbon Footprint: This involves the calculation of the carbon footprint of building materials, which encapsulates both embodied carbon and operational carbon emitted during at least 50 years of

Figure 24: BREEAM-NL sustainability evaluation model

operation. The construction material pyramid (Figure 2 in the source) aids this evaluation process.

2. Reused Content: This concerns the amount of virgin materials and recycled content, and the total time a material is kept in a product system.
3. Disassembly Potential & Longevity: The ability to replace and disassemble building components is evaluated, factoring in the time and type of disassembly as detailed in Table 2 of the source document.
4. Design Flexibility & Functional Adaptation: This involves assessing the potential of the building to undergo functional changes and adapt to new uses in the long-term, typically over 50-100 years.

Each building's circularity is assessed post audits, based on these four critical indicators (Figure 25). The final score of each building is determined by the cumulative score across all criteria. This model underlines the importance of used and recycled material content, an area where most assessed buildings were found lacking.

An alternative evaluation model used for evaluating circularity of architectural design is 'circularity design' guidance published by Platform CB'23 on July 2021. Platform CB'23 is an initiative that aims to connect parties within the construction sector who share ambitions towards circular economy [56]. In their published work about circularity design, there were 6 design strategies created for measuring and

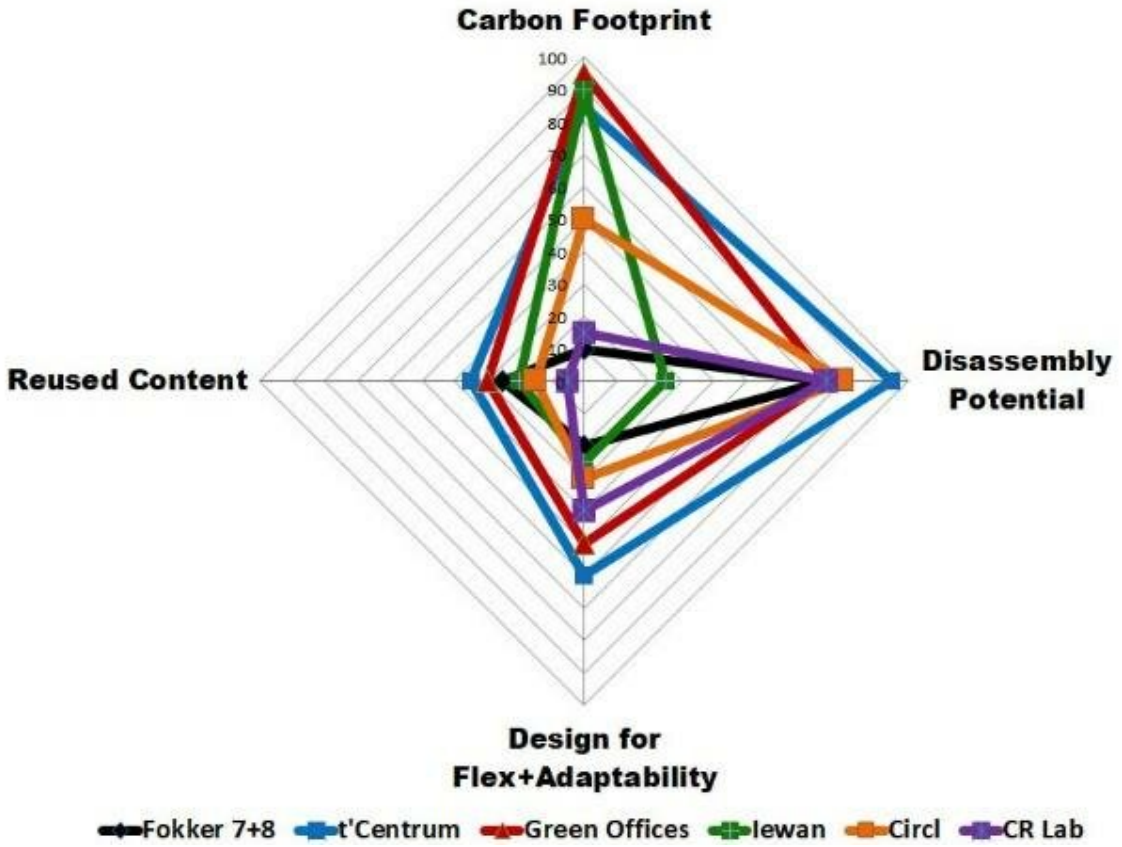


Figure 25: Comparison of the circularity of the six case studies from research by Attia and Al-Obaidy (2021)

providing guidance for circularity level of architectural designs, which can be applied to this research as an alternative of evaluating circularity level of architectural designs submitted by architects.

The 6 design strategies published by platform CB23 includes (Figure 26) :

1. Design for prevention : Focus on preventing the use of products, elements or materials to eliminate unnecessary structures, combining functions ingeniously, or devising entirely new solutions.
2. Design for life cycle impact reduction : Focus on the impact of circular materials use and consider its consequences to the environment and environmental performance at the end of lifespan.
3. Design for future proof : Focus on making design adaptable to future wishes and requirements and reusing the existing and used parts or structures of building.
4. Design with recycled objects : Focus on reuse of building products or building components or elements.
5. Design with secondary raw materials : Focus on designing with products or raw materials that have been used before or with residual flows from another product system.
6. Design with renewable raw materials : Focus on designing with renewable raw materials as much as possible.

These strategies are considered align well with the goals of the DAO framework, promoting sustainable and efficient architectural design. By incorporating these circularity principles into the DAO's evaluation system, architects will be encouraged to develop designs that not only meet the current needs but also consider future adaptability, materials' life cycle impacts, and the use of renewable or secondary raw

Figure 26: Circularity design guideline by platform CB23

materials. Consequently, this would drive the architectural community towards more sustainable and circular design practices, leading to a significant reduction in the environmental footprint of the built environment.

6.3.3 Multi-level Evaluation

The model utilized for the evaluation process in this research adopts the principles introduced in the study by Zou et al.[80]. Originally formulated for evaluating subway designs, however, the model can be easily adapted to the realm of architectural design. The model provides an integrative approach that encapsulates four primary dimensions: technology, human factors, aesthetics, and culture.

1. The **Technology** aspect represents the incorporation of innovative and advanced technologies within an architectural design. It measures the extent of smart technologies, the implementation of energy-efficient mechanisms, and the installation of advanced safety features. This allows the evaluation system to assess the design's potential for digital integration, environmental impact reduction, and increased safety.

2. **Human Factors** consider the design's ability to prioritize the needs, comfort, and overall experience of its users. It looks at how the architectural design can facilitate accessibility, enhance usability, and promote inclusiveness. This part of the evaluation model ensures that the design is user-centric and able to serve diverse users' needs effectively.

3. The **Aesthetic** dimension accounts for the visual appeal and creativity of the design, focusing on how well the design combines form and function. It evaluates the design's uniqueness, creativity, harmony, and its ability to create an engaging environment. This part of the model encourages architects to craft designs that not only serve practical purposes but also create visually engaging spaces.

4. Lastly, the **Culture** component evaluates the extent to which the architectural design resonates with the local context, historical relevance, and community identity. It examines the capacity of the design to reflect and respect the cultural heritage of the site and the community it serves. This ensures that the design contributes to preserving cultural identities and fostering a sense of community.

The integrated evaluation system (Table 6.1), inspired by Table 2 in research by Zou et al. [80], assigns scores to each of these four factors based on an extensive set of sub-criteria and filled in with response from interviewed architects. This holistic and nuanced scoring system ensures the overall quality of architectural designs and their potential impacts. By promoting a balanced consideration of technology, human factors, aesthetics, and culture, this model propels the creation of designs that are not just advanced and efficient but also engaging, inclusive, and culturally significant. This way, the model serves

as a tool that encourages architects to strive for designs that are sustainable, user-focused, aesthetically appealing, and culturally sensitive, contributing to the larger goals of the architectural field.

Criterion layer	Index layer	Description
Technology	Integration of smart technologies	Incorporation of automated and intelligent systems for convenience and efficiency.
	Energy efficiency	Use of energy-saving mechanisms and renewable energy technologies.
	Safety features	Incorporation of advanced safety and security features.
Human factor	Accessibility	Consideration of diverse user needs, such as universal design principles.
	Usability	Design facilitates ease of use and improves the user experience.
	Inclusivity	Design accounts for a diverse range of users' needs and abilities.
Aesthetics	Uniqueness	Originality and innovative aspects of the design.
	Creativity	Artistic and inventive aspects in design execution.
	Harmony	Cohesiveness and balance in design elements.
Culture	Local context	Design reflects and harmonizes with the local landscape and architecture.
	Historical relevance	Design acknowledges and respects historical and cultural heritage.
	Community Identity	Design contributes to fostering a sense of community and belonging.

Table 6.1: Multi-level evaluation

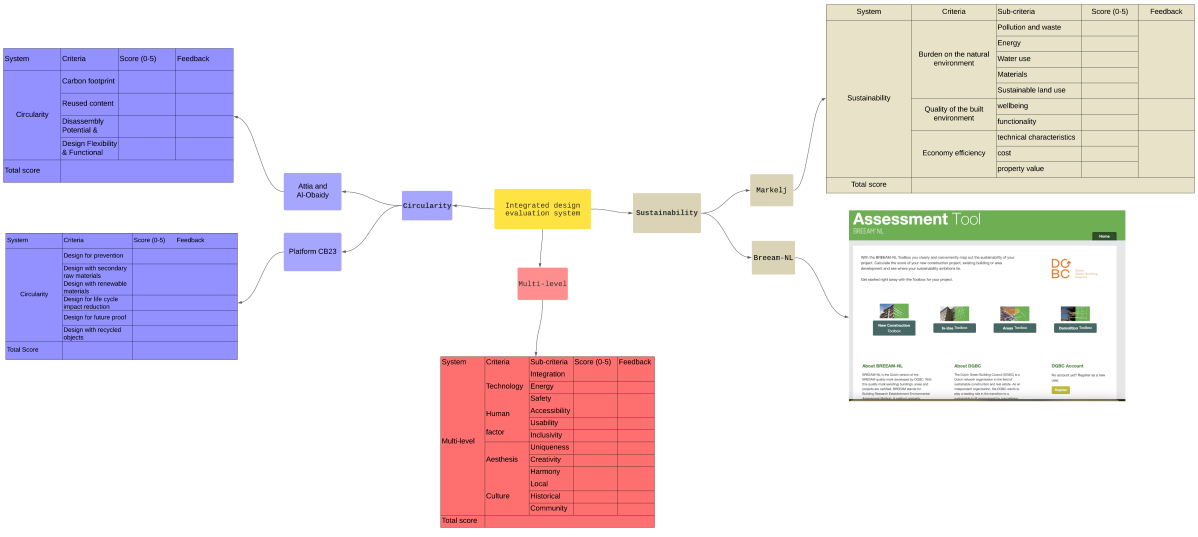


Figure 27: Integrated evaluation system

6.3.4 Integration of design evaluation systems

The evaluation systems established for sustainability, circularity, and multi-level considerations have been synthesized into an integrated system (Figure 27, intended as a reference for DAO members during the

architectural design evaluation process. This comprehensive evaluation process comprises three main phases:

1. First Phase: Sustainability - In this phase, DAO members need to select between the 'sustainability evaluation system by Markelj' and 'system by BREEAM-NL' for evaluation. Each system provides a unique approach to sustainability:
    - The Markelj system (Figure 48) originates from academic research and presents a holistic evaluation method encompassing three main pillars: the burden on the natural environment, the quality of the built environment, and economic efficiency. These pillars encompass factors such as pollution and waste, energy, water use, materials, sustainable land use, wellbeing, functionality, technical characteristics, cost, and property value.
    - The BREEAM-NL system, on the other hand, is an industry-standard developed by the Building Research Establishment (BRE). It provides a robust and well-rounded evaluation process covering water, materials, waste, pollution, land use, ecology, management, health, energy, and transportation. Being an industry-standard, it also has the advantage of widespread recognition and acceptance in the field.
2. Second Phase: Circularity - In this phase, DAO members need to select between the 'circularity evaluation by Attia and Al-Obaidy's research' and 'system by platformCB23'. Each system provides a unique lens to assess circularity:
    - Attia and Al-Obaidy's research system (Figure 49) examines the circularity of a design in terms of its carbon footprint, reused content, disassembly potential and longevity, and design flexibility and functional adaptation. This research-based system gives a more in-depth look into the circularity of designs from a lifecycle perspective.
    - The platformCB23 system, a standard developed by a renowned foundation, presents a broader view of circularity (Figure 50), looking at design for prevention, design with secondary raw materials, design with renewable materials, design for lifecycle impact reduction, design for future proof, and design with recycled objects.
3. Third Phase: Multi-level - In this phase, DAO members will use a customized evaluation system to assess the design on a variety of aspects (Figure 51), including culture, technology, human factors, and aesthetics. This phase aims to evaluate how well the design integrates into the local context and the overall harmony of the project in its setting. Factors like uniqueness, creativity, local relevance, and inclusivity are considered to provide a comprehensive understanding of the design's multi-level impacts.

In the three phases of the evaluation process, DAO members are tasked with scoring the design based on the specific criteria outlined in each selected system. This comprehensive approach ensures that a variety of aspects are considered, from sustainability and circularity to multi-level factors such as cultural context and aesthetic harmony. Feedback will be provided in tandem with these scores, encouraging constructive dialogue and continuous improvement. To streamline this process, designated evaluation forms are provided for each phase. In the case of the BREEAM-NL system during the sustainability phase, the evaluation will follow BREEAM's official procedures. This method of integration guarantees a cohesive and standardized approach, balancing the benefits of various research-based insights and industry standards in a practical, actionable manner.

6.3.5 Proof-of-Concept: Applying the Integrated Design Evaluation System

This section presents a Proof-of-Concept (POC) that showcases the practical application of the integrated evaluation system in a real-world context. The aim is to demonstrate the step-by-step process of evaluating a hypothetical architectural design project through each of the three phases: Sustainability, Circularity, and Multi-level considerations. A select subset of the criteria from each phase will be considered for this demonstration (Figure 31), ensuring simplicity and better understanding of the evaluation process. This application of the evaluation system provides an insight into its operation, illustrating how its comprehensive approach can effectively guide design decisions and improvements in real-life architectural projects.

Sustainability Evaluation

In the first phase, the project is evaluated for sustainability using the criteria outlined in the sustainability evaluation system. Figure 28 presents the filled evaluation form for the sustainability phase. As shown in the table, the design was awarded a score of 37 out of 50, indicating a solid commitment to sustainability. The evaluator provided constructive feedback for each criterion, highlighting areas of success such as excellent pollution and waste reduction methods and areas for potential improvement, like enhancing water recycling practices.

System	Criteria	Sub-criteria	Score (0-5)	Feedback
Sustainability	Burden on the natural environment	Pollution and waste	5	Excellent pollution and waste reduction methods. Adequate energy efficiency, consider more renewable solutions Fair water management, could enhance water recycling. Good use of sustainable materials, keep exploring alternatives. Excellent land use, impressive integration of nature.
		Energy	3	
		Water use	3	
		Materials	4	
		Sustainable land use	5	
	Quality of the built environment	wellbeing	3	Promotes wellbeing, but consider more natural lighting and ventilation. Good functionality and adaptability, consider future-proofing.
		functionality	4	
	Economy efficiency	technical characteristics	5	Excellent use of efficient technology. Needs focus on lifecycle cost for better financial sustainability. Moderate value addition, consider improving energy efficiency.
		cost	2	
		property value	3	
Total score	37/50			

Figure 28: sustainability evaluation system

Circularity Evaluation

Following the sustainability evaluation, the design is assessed for circularity, taking into account design for prevention, design with secondary raw materials, design with renewable materials, design for life cycle impact reduction, design for future proof, and design with recycled objects. As indicated in Figure 29 , the design achieved a score of 19 out of 30. This reflects the design's moderate success in achieving circularity, with particularly good consideration for future-proof design. However, the feedback indicates the potential for improvement in the use of recycled objects and secondary raw materials.

Multi-level Evaluation

In the final phase, the project is assessed on multiple levels including technology, human factors, aesthetics, and culture. The scores and feedback presented in Figure 30 demonstrate the project's high level of technological integration and aesthetic consideration, with a total score of 48 out of 60. However, the feedback also suggests potential improvements, particularly in terms of historical relevance in the cultural context, and usability and accessibility under human factors.

In summary, this Proof-of-Concept demonstrates the practical application of the integrated evaluation system, providing a clear, step-by-step process to assess architectural design projects. By considering sustainability, circularity, and multi-level aspects, this system ensures a comprehensive review that drives better design decisions and continuous improvement. Each phase of the evaluation process presents

System	Criteria	Score (0-5)	Feedback
Circularity	Design for prevention	3	Adequate waste prevention, consider more reduction methods.
	Design with secondary raw materials	3	Good use of secondary materials, explore more options.
	Design with renewable materials	3	Fair use of renewables, could increase the variety.
	Design for life cycle impact reduction	3	Decent life cycle reduction, but improvements can be made.
	Design for future proof	5	Excellent future-proofing design, highly adaptable.
	Design with recycled objects	2	Limited use of recycled objects, needs improvement.
Total Score	19/30		

Figure 29: circularity evaluation system

System	Criteria	Sub-criteria	Score (0-5)	Feedback
Multi-level	Technology	Integration of smart technology	4	Excellent implementation of safety features and energy-efficient solutions, making a significant positive impact. Good integration of smart technology; exploring more advanced or innovative tech could enhance this further.
		Energy efficiency	5	
		Safety features	5	
	Human factor	Accessibility	3	Good attention to inclusivity, allowing diverse user groups to feel welcome and comfortable. However, there is room for improvement in accessibility and usability, ensuring the design is user-friendly for all.
		Usability	3	
		Inclusivity	4	
	Aesthesis	Uniqueness	5	Outstanding in terms of uniqueness, creativity, and harmony. The design stands out for its innovative features and well-blended aesthetics, creating a pleasing visual experience.
		Creativity	5	
		Harmony	5	
	Culture	Local context	4	Commendable integration with the local context, showing a clear understanding of the surrounding environment. However, an increased focus on historical relevance and better representation of community identity could further enhance the cultural aspect.
		Historical relevance	2	
		Community identity	3	
Total score	48/60			

Figure 30: Multi-level design evaluation system

an opportunity to give constructive feedback that can guide design modifications and enhancements. Ultimately, this robust and standardized approach empowers designers and evaluators to integrate sustainability, circularity, and multi-level considerations into the core of architectural design practice.

6.3.6 Integration with membership smart contract

In this section, the focus is on how the evaluation system is integrated with the membership smart contract. The evaluation system, while developed as a standalone module, works closely with the DAO's membership smart contract.

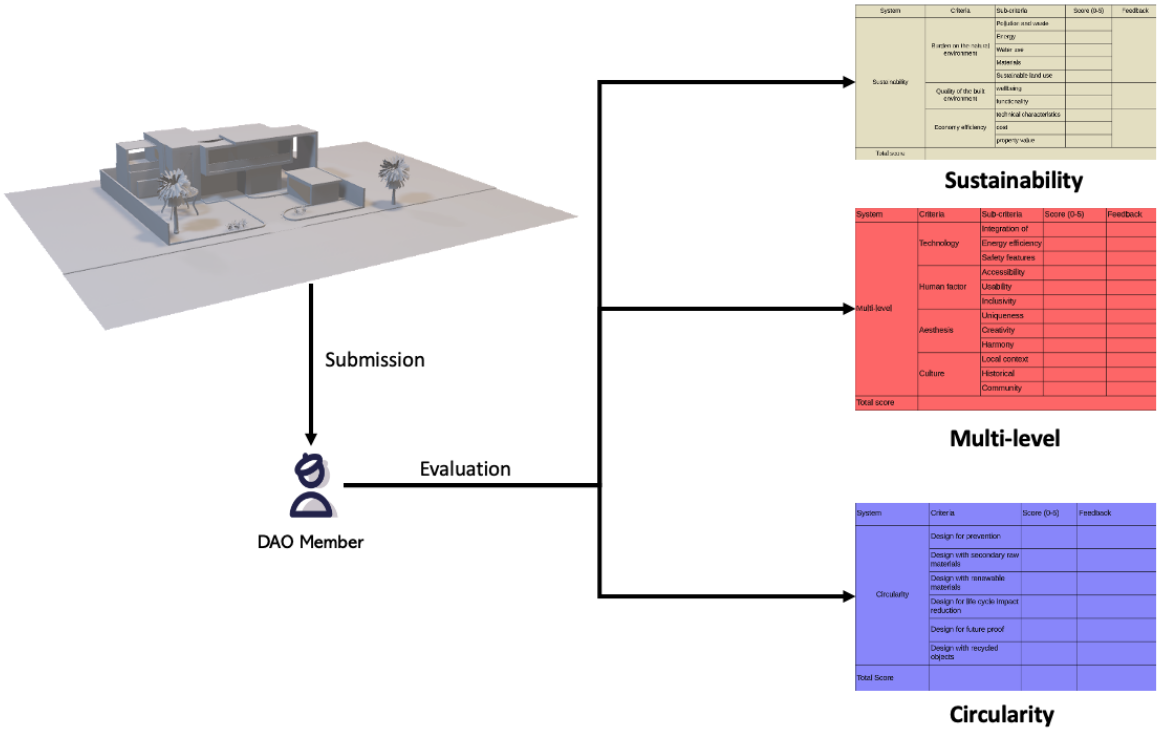


Figure 31: Application of desgin evaluation system

- Evaluation committee: A crucial component of this integration process. This temporary body is composed of DAO members with relevant expertise in relation to the design under consideration. The committee's task is to manage the evaluation phase of the design, provide feedback to the architect, and prepare the design for the next level. Participation from both architects and committee members is incentivized through engagement rewards in the form of DAO tokens. The committee is disbanded upon the completion of its tasks.
- Evaluation system: Functions as the central mechanism for the evaluation of architectural designs within the DAO. Designed to be inclusive and comprehensive, the system aims to provide an objective evaluation of a design's value based on a range of criteria. This includes sustainability, social impact, cultural value, and local compatibility. The multi-dimensional approach to evaluation ensures a thorough analysis of the architectural designs and nurtures high-quality projects.
- Dynamic nature of the evaluation system: As part of the integration, it's important that the evaluation system is dynamic and evolves in sync with the latest trends and standards in the architectural industry (figure 32). DAO members are crucial to this, providing continuous input and improvements to the system. This approach fosters a culture of continuous learning and improvement, enhancing the credibility and effectiveness of the evaluation process.

Through this integration, the evaluation system and the membership smart contract interact symbiotically to facilitate a streamlined, adaptive, and collaborative approach to architectural evaluation.

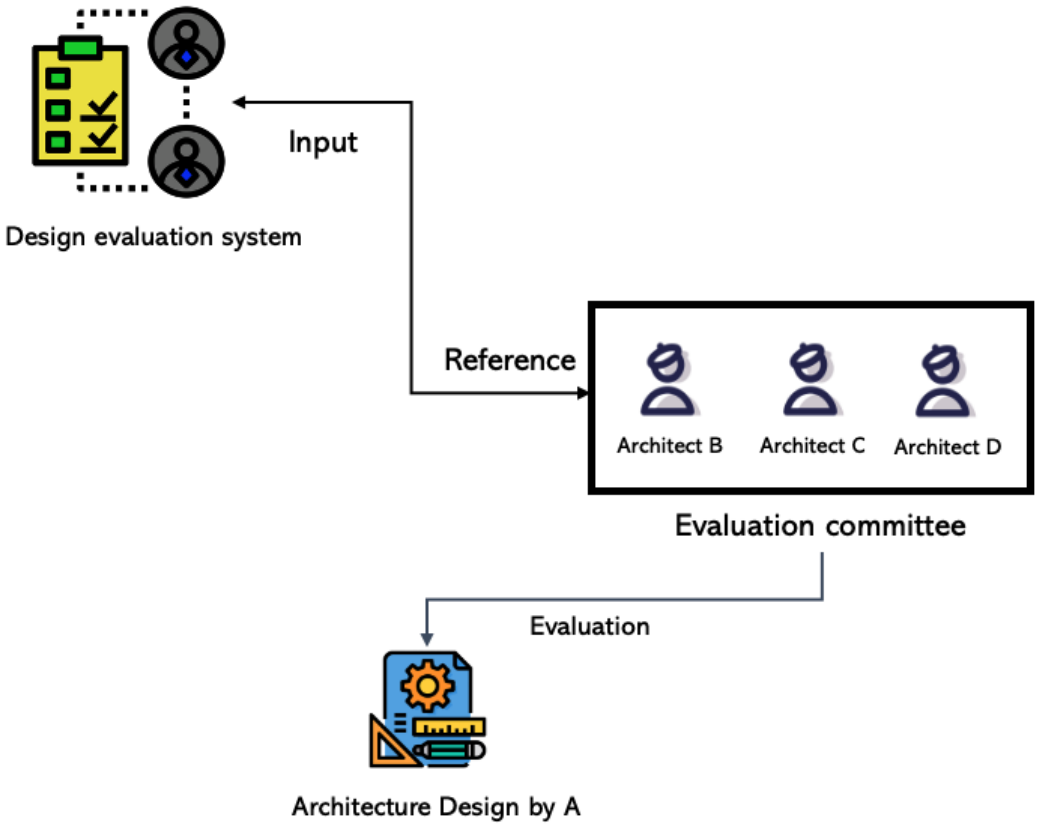


Figure 32: Evaluation system with committee

Chapter 7

Artifact Validation

As the final phase of the Design Science Research (DSR) methodology, artifact validation is of paramount importance in determining the feasibility and effectiveness of the proposed solutions to architectural design evaluation. This chapter will dive into the validation of main components of the framework, including smart contract of membership system and design evaluation system. It is through this validation process that the practicality and value of the DAO framework, along with its various components, are validated and assessed. This chapter represents the junction where theoretical constructs are put to practical scenarios, thereby reinforcing the credibility and applicability of the DAO framework within the decentralized governance landscape and the field of architectural design.

7.1 Validation approach

Artifact validation, as mentioned in the Design Science Methodology by Wieringa [74], aims to foster a design theory rooted in the context of an artifact, this theory provides the means to predict the outcome when the artifact is deployed in its target problem context. The primary challenge of validation research is that it's conducted prior to implementation, often without a real-world problem context or actual implementation in place and so is the fact in this research, there is no suitable implementation time and place for a DAO to be built in a short period of time. To address this, Wieringa suggests that design science researchers employs validation models to simulate implementations, using a prototype of an artifact in interaction with a model of the intended problem context. This enables the development of a design theory about the artifact-context interaction.

Next, the validation approach of the DAO framework will now be discussed. The validation process of the developed framework is designed to comprehensively assess its two main components: the smart contract for the membership system, and the design evaluation system. Both components play crucial roles in the overall functioning and efficiency of the framework, and thus require meticulous validation.

The smart contract for the membership system forms the backbone of the DAO framework, establishing the rules and functions of the membership within the decentralized organization. In order to validate this component, simulation tests will be conducted as per the methodology suggested by Wieringa [74]. These tests will aim to simulate the contract's performance in various situations, including different numbers of members, variable transaction loads, and diverse member interactions. The purpose of these tests is to ensure the robustness, efficiency, and scalability of the smart contract under different scenarios. By replicating the intended problem context, the simulation tests provide a predictive assessment of the contract's functionality and resilience, making it an effective validation strategy.

As discussed by Dresch et al. [23], the premise of design science research is to ensure practical validity alongside scientific rigor, aiming to solve specific research problems and achieve the anticipated results. In this research, the second component of the developed DAO framework, the design evaluation system, embodies this philosophy and is tasked with assessing architectural designs submitted to the DAO,

with a validation process carefully designed to ensure objectivity, reliability, and comprehensiveness. To achieve practical validity, the validation process integrates expert review, allowing the system to be reviewed by professionals endowed with extensive knowledge and experience in architecture and design. These experts are able to offer invaluable insights into the evaluation criteria and can scrutinize how the system accommodates different design philosophies and architectural paradigms. In this way, the expert review not only adds depth to the validation process but also ensures that the design evaluation system is optimally configured to encourage innovative, high-quality architectural design within the DAO framework.

7.2 Simulation tests

The chosen framework for the simulation test is agent-based modeling. Agent-based modeling (ABM) is a computational approach that enables researchers to create, analyze, and experiment with models composed of agents that interact within an environment. In this framework, each agent(simulated participant) operates autonomously, following a set of rules and behaviors defined by the researcher. ABM is particularly useful for examining complex systems and observing emergent phenomena, as it allows the researcher to manipulate the behaviors and interactions of individual agents, the environment, and the overall system [41].

In the context of this research, ABM will be employed to create the high-fidelity, virtual environment for the simulation test. It will allow the replication of diverse scenarios that may be challenging to execute in a real-world context when interacting with such a smart contract. Six different scenarios will be modeled and each designed to verify a specific functionality or set of functionalities of the artifact. These scenarios, chosen to simulate potential real-world use-cases, will ensure that the artifact performs optimally under a range of conditions and situations. More importantly, the agent-based modeling framework will provide the flexibility and control necessary to test the robustness of the artifact and its performance across these scenarios, thus forming a crucial part of the validation process.

7.2.1 Test participants

There will be 6 simulated participants represented by 6 Ethereum wallet and each wallet has been credited with enough Ethereum token balance for the convenience of test (table 7.1). Wallets A, B, and C represent the architects involved in the DAO but are not members yet. They are key players in the operation of DAO activities. These wallets can be thought of as general architects. Wallets D, E, and F, on the other hand, represent DAO members who are also architects. These DAO members can be seen as founding members of DAO and temporarily are in charge of DAO operations until more members join in. Their role is essential to the distributed and democratic nature of a DAO, ensuring that the DAO is governed by consensus rather than a central authority.

Index	Name	Wallet address
A	Architect A	0xd625E0B8eBB492bbfB9a4fE5C7CbC07Ab5126B28
B	Architect B	0x4B26a638EC85457a8c683Dee79100A7C77374460
C	Architect C	0xF50d153f8524CD74b2beB1AeaA5C796cc3F72322
D	DAO member D	0xBd4230B9243E223A469B36fE2a6556Fc1280926b
E	DAO member E	0xCa06331BC0f6Bf1021524bA605517E74e78074B4
F	DAO member F	0x233062bDC15e89FB85aC53cd0253b2ecdf8c63a8

Table 7.1: Simulated participants

7.2.2 Test environment

First, the simulation test will be conducted on the Sepolia testnet of Ethereum(Figure 33). Sepolia is one of the Ethereum testnets that offers a free and open-source testing environment [5]. Testnets like

Sepolia provide developers with a nearly identical but separate blockchain where they can test their smart contracts and DApps without any real-world consequences or costs. And more importantly, the tests are conducted publicly on blockchain, therefore, it is reproducable for future researchers.

Choosing Sepolia as the testing environment has multiple advantages. First, it operates just like the Ethereum mainnet, providing a realistic environment for testing. Any behavior observed on Sepolia should, in principle, replicate on the Ethereum mainnet. Second, transactions on Sepolia require "test Ether" which can be obtained for free, so developers can test their applications extensively without worrying about incurring costs. Finally, it's a safe environment to simulate and understand the behavior of DApps and to detect and correct any bugs or vulnerabilities before deploying the contract on the main Ethereum network.

Figure 33: Sepolia testnet

7.2.3 Test scenarios

1. **Scenario 1: Architect A applies to join the DAO and gets approved.**
   In the first scenario, Architect A takes the initiative to apply for membership within the Decentralized Autonomous Organization (DAO). The application is meticulously evaluated according to predetermined criteria and guidelines set by the DAO. In this instance, Architect A's application meets the specified requirements and is approved. This scenario tests the functionality of the smart contract that enables new member onboarding and verifies that the approval process functions correctly.

2. **Scenario 2: Architect B applies to join the DAO but gets rejected.**
   The second scenario involves Architect B, who also seeks membership in the DAO. However, unlike the previous scenario, Architect B's application fails to satisfy the set criteria and guidelines of the DAO. Consequently, the application is rejected. This scenario is designed to test the smart contract's functionality in handling application rejections, thus ensuring that the DAO membership criteria are enforced correctly.

3. **Scenario 3: Architect B applies for evaluation and gets confirmed.**
   In this scenario, DAO Member C applies for evaluation. The smart contract governing the DAO conducts the evaluation and validates Member C's status. This scenario tests the mechanism of the smart contract in evaluating and confirming member statuses. This procedure is crucial for various DAO operations, including voting rights and task assignments.

4. **Scenario 4: DAO member E applies to remove another member D and gets approved.** In the fourth scenario, DAO Member E submits an application to remove Member D from the DAO. The smart contract facilitates the removal process, and in this case, the application to remove Member D is approved. This scenario is designed to verify the smart contract's capability of handling member removal procedures, ensuring that it can process and implement such decisions effectively.

7.2.4 Metrics for success

The primary metric for success in the validation process is the successful execution of transactions within the smart contract environment. This refers to actions that modify the state of the contract such as adding, evaluating, or removing members from the DAO. Essentially, a transaction is considered successful if it's correctly processed, executed, and leads to the accurate modification of the contract's state as per the intended effect. Therefore, the effectiveness and correctness of the smart contract are directly measured by the successful completion of each transaction.

7.2.5 Run simulations

Contract deploy

In the context of this research, Hardhat is utilized to simplify the compiling and deployment of smart contracts on the Sepolia testnet of the Ethereum network. Hardhat, as an Ethereum development environment, streamlines tasks like testing, debugging, and smart contract deployment, thereby proving useful for developers (Hardhat Documentation, 2023). The initial step involves deploying the smart contract using Hardhat. The contract has been successfully deployed (Figure 34) and verified with Hardhat on the Sepolia testnet. The contract address is 0xACea9339A78746DDf06E96Ac3DA1Ea13F1c0BABE, and it can be viewed at `https://sepolia.etherscan.io/address/0xacea9339a78746ddf06e96ac3da1ea13f1c0babe` At this point, the contract is ready for other users to interact with (Figure 35). During the deployment of the smart contract, the wallets corresponding to DAO members D, E, and F are directly configured as DAO members. This ensures the DAO has sufficient founding members to begin operations, as every application from architects requires approval from at least three members.

Scenario 1: Architect A applies to join the DAO and gets approved

1. **Application**: Architect A (also identified as wallet A) initiates the process by applying to join the DAO. This application is submitted through interaction with the smart contract. On the Etherscan page, a transaction from wallet A to the DAO's smart contract address (Figure 36) can be identified and the input data of this transaction would contain the method name which corresponds to 'apply to join'.

2. **Confirmation**: Once the application is submitted, it is reviewed by randomly selected DAO members. These members interact with the smart contract by calling a function like 'confirm Application'. On Etherscan, these would appear as individual transactions from each of the confirming DAO member's wallets to the DAO's smart contract address (Figure 37). The input data of these transactions would contain the method name which corresponds to 'confirm Application' and can be found in `https://sepolia.etherscan.io/tx/0x842f2ac93affa377d416d5d800aa4d12829e0b7f9550df6218d4ac0b654a`

3. **Joining the DAO**: After receiving confirmation from the selected DAO members, Architect A can now join the DAO. This is done by calling another function, likely named something like 'Join DAO'. On Etherscan, this would appear as another transaction from wallet A to the DAO's smart contract address. The input data of this transaction would contain the method name which corresponds to 'Join DAO', the transaction can be found through the link : `https://sepolia.etherscan.io/tx/0xb2ba4550a3cfa890a07dc6cbca329b99c2834622fb54aaa1a54775ace122f463`

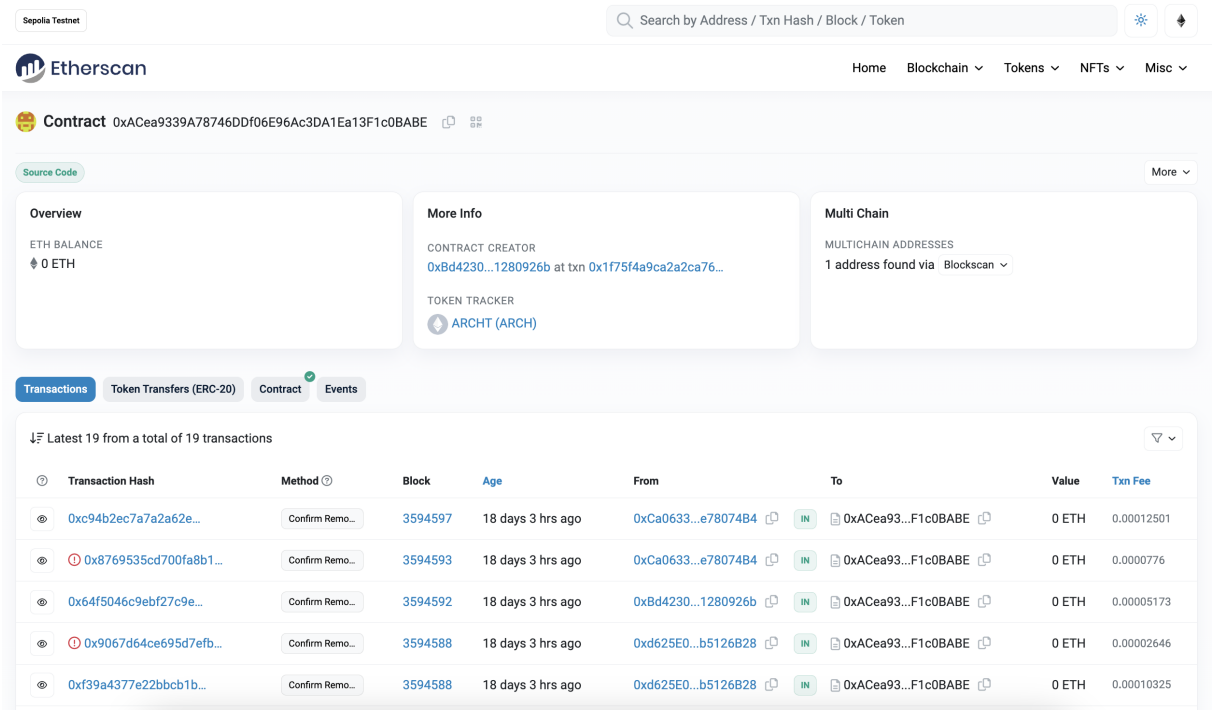


Figure 34: Deployed smart contract

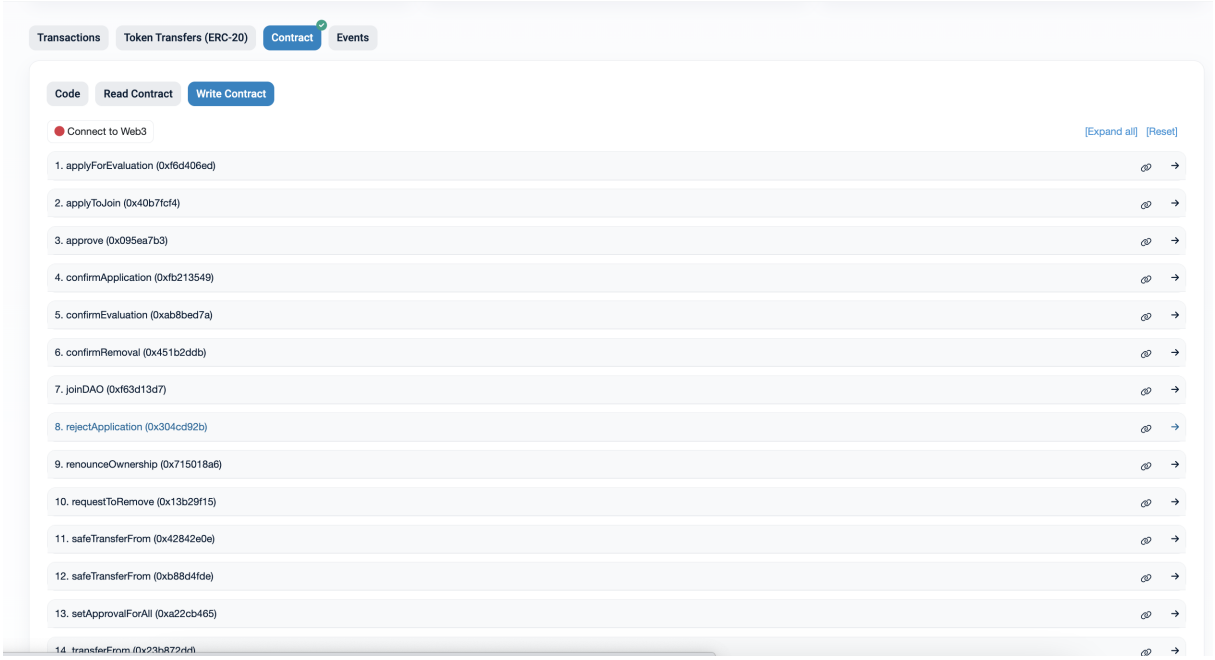


Figure 35: Contract functions

4. **Minting Membership NFT**: Finally, after successfully joining the DAO, Architect A mints a membership NFT (Non-Fungible Token) (Figure 38). This NFT serves as a marker or proof of Architect A's membership in the DAO. On Etherscan, the minting of this NFT would likely show as a transaction from the DAO's smart contract address to wallet A, indicating the transfer of a new NFT.

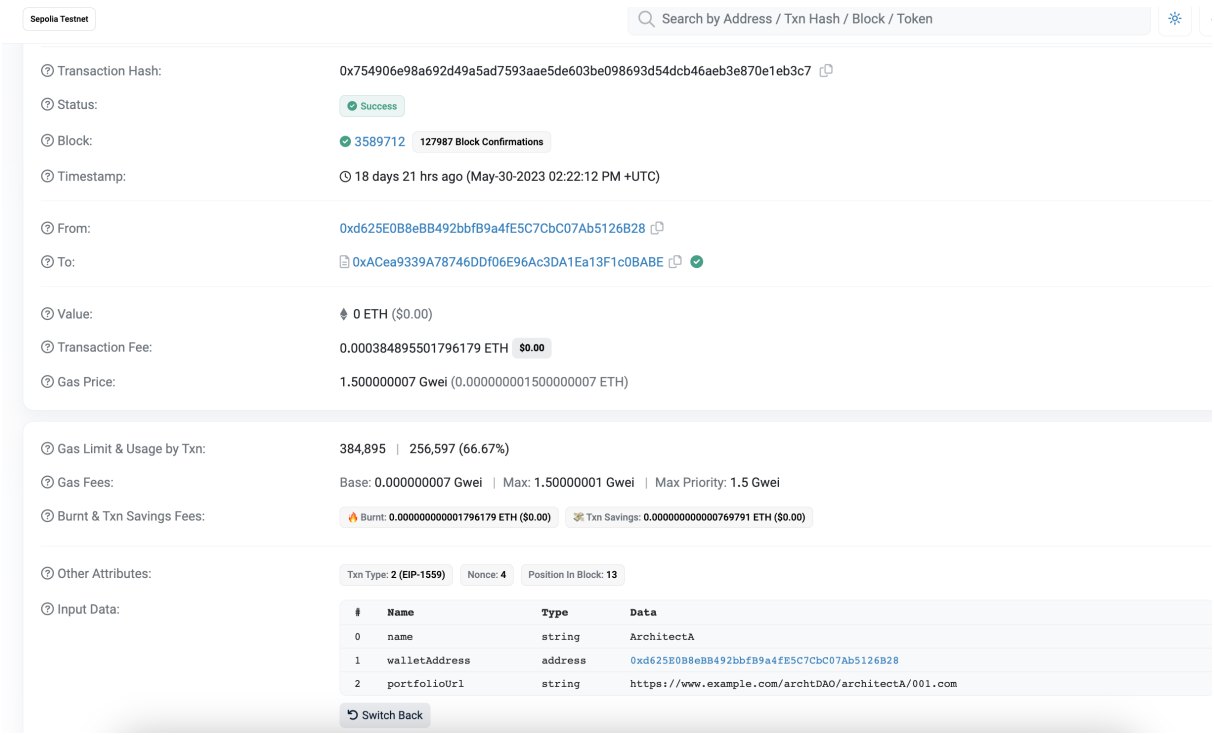


Figure 36: Contract interaction for application

Scenario 2: Architect B applies to join the DAO but gets rejected.

For architects who are not considered qualified to join the DAO by DAO members, his or her application will be rejected by the DAO member, once one of the evaluators rejected the application, the application process will terminate and the application will be abandoned immediately.

1. **Application**: Architect B (also identified as wallet B) initiates the process by applying to join the DAO. This application is submitted through interaction with the smart contract. On the Etherscan page, a transaction from wallet B to the DAO's smart contract address (Figure 39) can be identified and the input data of this transaction would contain the method name which corresponds to 'apply to join'. The transaction can be viewed at : `https://sepolia.etherscan.io/tx/0xc3a7dcfd7750896be85505e50f5a86032a1d9ebb3a2be33ac26afdd404cbd300`

2. **Rejection**: Architect A (already a DAO member now) was selected as an evaluator in this application and considered architect B's application invalid and disqualified, therefore, architect A rejected the application by architect B, which leads to the termination of application process (figure 40).

3. **Confirmation**: And the application status shows invalid on blockchain as well after the application process has been terminated by architect A by calling 'reject application'.

Scenario 3: Architect B applies for evaluation and gets confirmed.

As architectural design evaluation, which typically occur outside the blockchain environment in real-world scenarios, and this validation section only focuses on blockchain transactions, not on the evaluation of architectural designs, therefore, the architectural design evaluation will not be included nor validated within this research.

1. **Apply to be evaluated**: In this scenario, Architect B has applied for a peer evaluation by another DAO member E. DAO member E will need to apply for evaluation through smart contract by calling

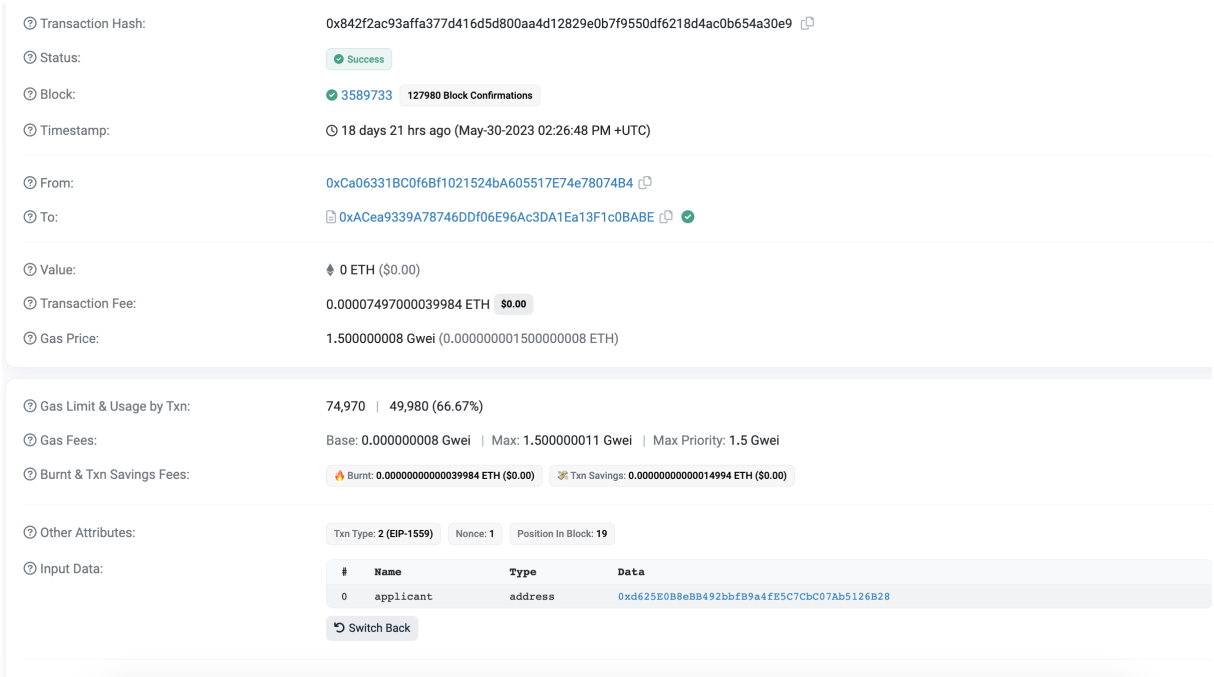


Figure 37: Contract interaction for confirming application

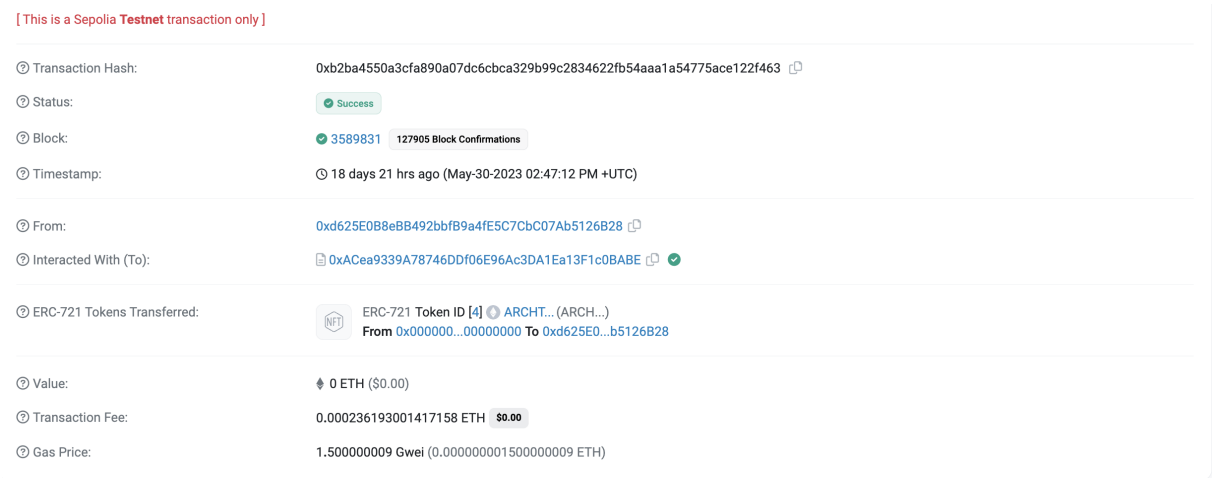


Figure 38: transactions for joining the DAO

function 'apply for evaluation', meanwhile, he or she will send the to-be-evaluated architectural design to evaluators in other format than blockchain (Figure 41).

2. **Confirm the evaluation request**: In the scenario of confirming the evaluation, DAO member E is providing confirmation for the evaluation that was requested by DAO member B (Figure 42). In order to confirm the evaluation, DAO member E calls the 'confirmEvaluation' function of the smart contract, using the evaluation ID as the parameter. The evaluation ID is used to identify and confirm the specific evaluation request. By confirming the evaluation, DAO member E is essentially validating the work or input of DAO member B. The transaction for this evaluation confirmation can be viewed at the following link on the Sepolia Etherscan: `https://sepolia.etherscan.io/tx/0xa099df317a0e326e7670b79e6435eb95b886d49281d3578e4d23d8283cb157d6`.

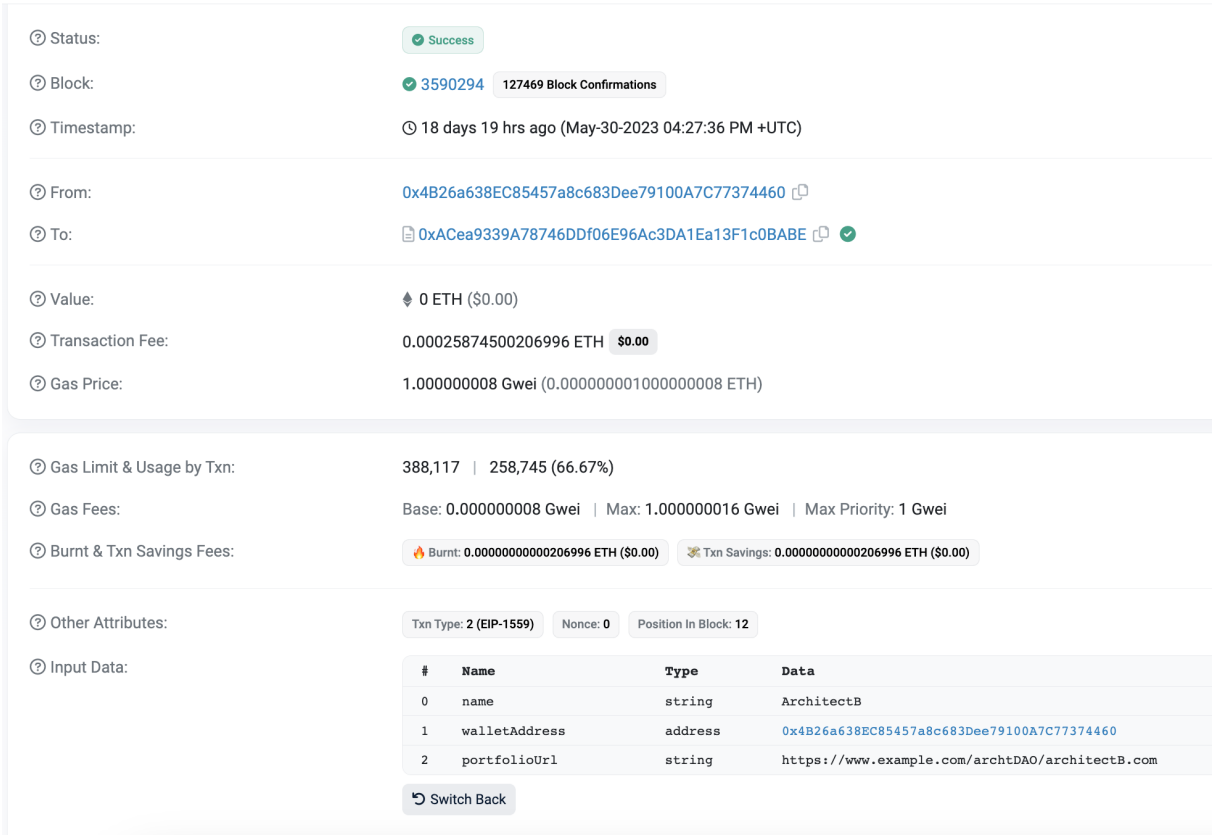


Figure 39: Application by architect B

Scenario 4: DAO member E applies to remove another member D and gets approved

1. **Request removal**: In this scenario, DAO member A has requested the removal of DAO member F (Figure 43). Member A started this by calling the 'requestRemoval' function in the smart contract, indicating that they believe member F's participation in the DAO is no longer beneficial. This could be due to various reasons such as misconduct, non-performance, or violation of the DAO's principles. The request for removal is a significant event and is permanently recorded on the blockchain, ensuring the process is transparent and accountable. The transaction relating to this request can be viewed on the Sepolia Etherscan at this link: `https://sepolia.etherscan.io/tx/0xc82d1eb8ecdb8cda507043d4e45a3998728c3bb4cecda138764fa0412e75186c`. This procedure highlights the democratic nature of the DAO, where members can voice their concerns and take actions to safeguard the integrity of the organization.

2. **Removal confirmation**: In this chain of events, the DAO has collectively affirmed the decision to remove DAO member F, through a series of confirmations by the other members. Each of these members has called the 'confirmRemoval' function in the smart contract. These confirmations are three crucial steps in the DAO governance, highlighting the consensus-based nature of the organization.

   (a) The first confirmation came from a DAO member whose transaction can be tracked at `https://sepolia.etherscan.io/tx/0xf39a4377e22bbcb1b2afd388068a284b667456d97fd662363ac5f0e3583f239`

   (b) The second confirmation followed suit, further corroborating the removal request. This can be verified at :`https://sepolia.etherscan.io/tx/0x64f5046c9ebf27c9e7f9bec9c5a458875da11d051023e9b4`

   (c) Finally, the last required confirmation was approved, thus finalizing the decision. This last transaction is traceable at `https://sepolia.etherscan.io/tx/0x64f5046c9ebf27c9e7f9bec9c5a458875da1`

   Upon the third confirmation, the DAO's smart contract immediately enacts the removal by burning the membership NFT of DAO member F, thus erasing their membership status. Consequently, their wallet address no longer appears in the DAO member list, signifying the successful expulsion

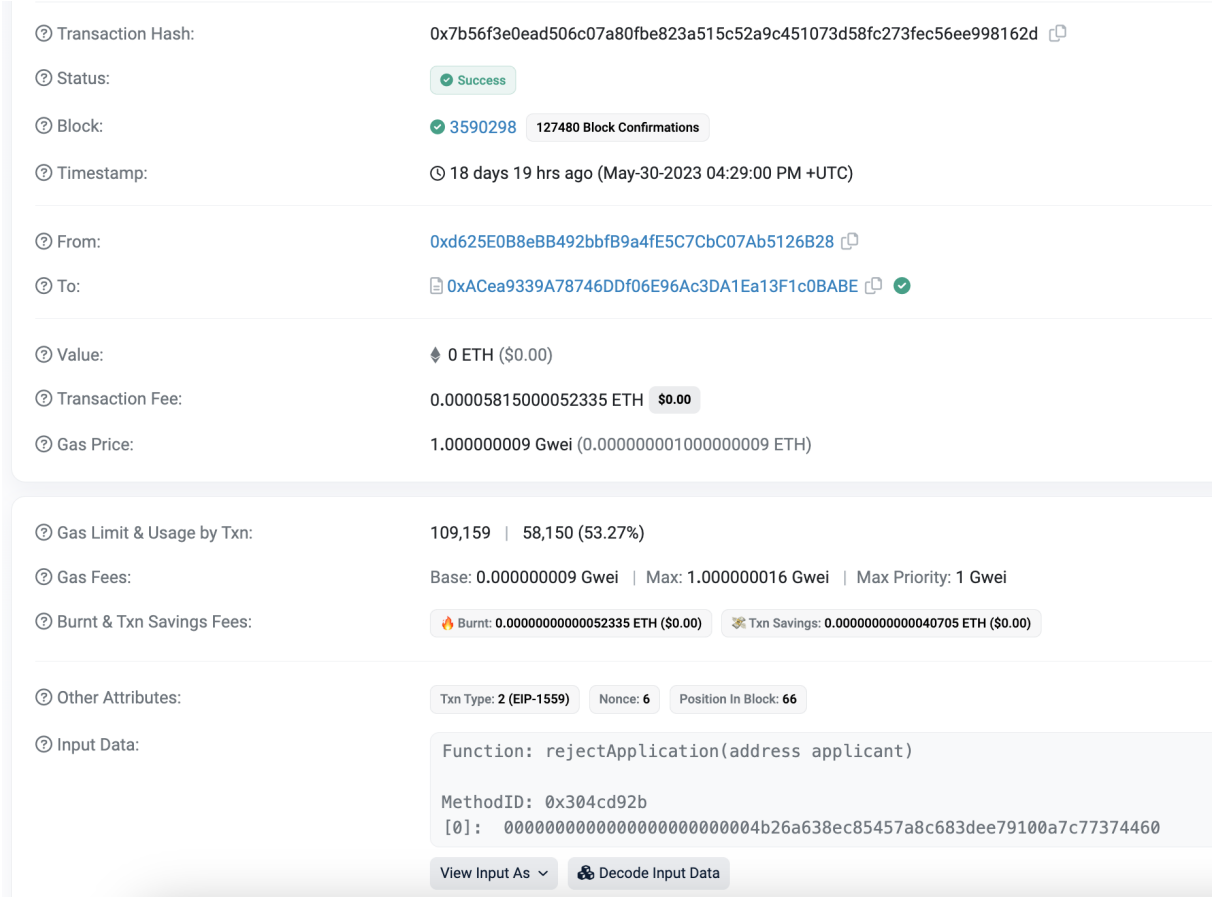


Figure 40: Reject application by architect B

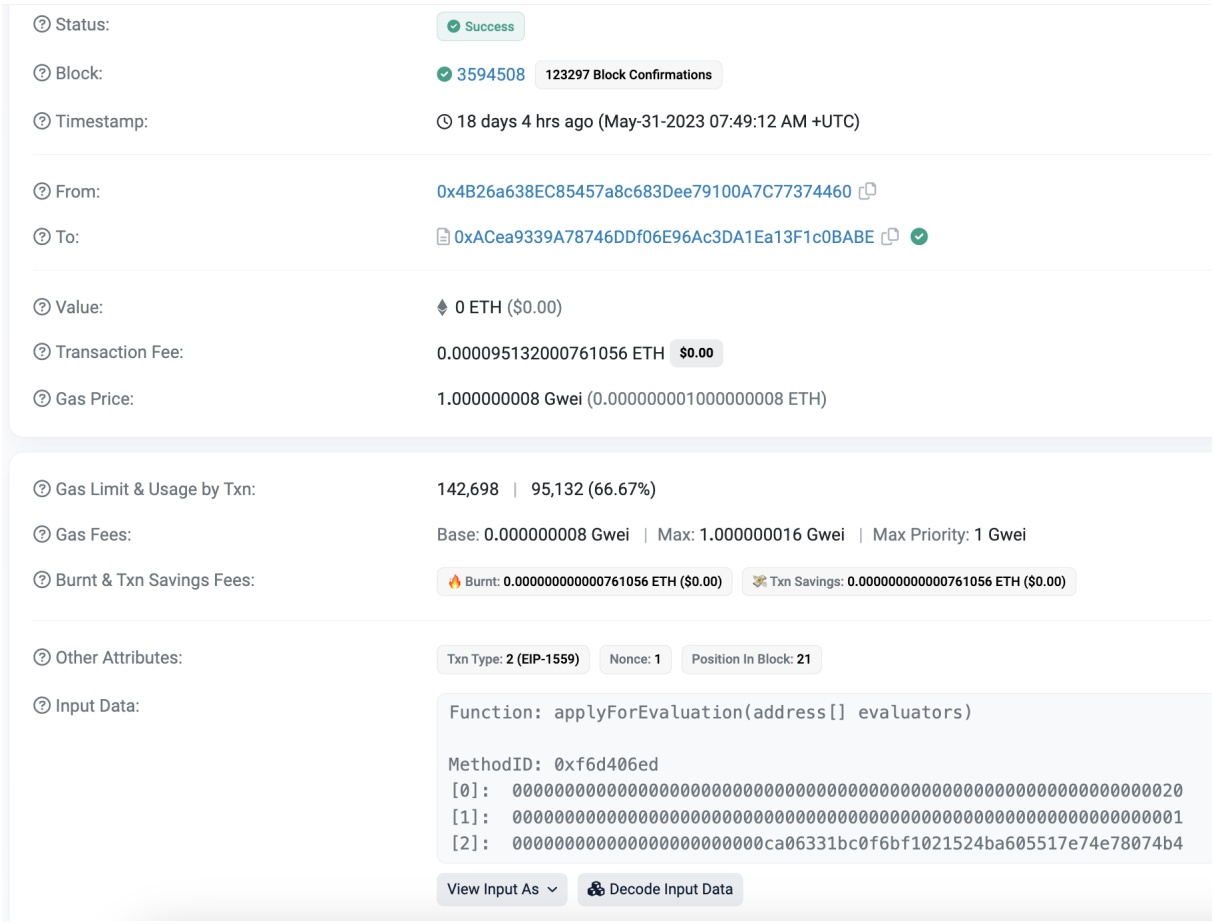


Figure 41: ArchitectB applies for evaluation

from the DAO (figure 44. This exemplifies the power of decentralized governance in managing the member composition of the DAO.

7.2.6 Simulation result discussion

Reflecting on the simulation test, two main areas have been identified where potential improvements can be made to augment the operational efficiency and user convenience of the DAO. These enhancements are aimed to smoothen interactions among DAO members and enhance the flexibility of the DAO's functionality.

1. **Removal Request Evaluators List**
   The process of removing a member involves the consensus of other DAO members. Currently, DAO members need to manually notify others to confirm a removal request. A beneficial upgrade would be the automatic generation of an evaluators list whenever a removal request is initiated. This list could be displayed on a shared dashboard, sent out via notifications, or embedded into the blockchain transaction itself as metadata. The integration of such a feature would streamline the process and eliminate the need for manual notifications. This would save time, reduce the chance of missing out any member, and generally make the process more efficient and user-friendly.

2. **Removal of 'joinDAO function'**
   The removal of the 'joinDAO function' in the DAO framework was an important improvement aimed at streamlining the registration process and reducing the associated gas costs for architects. Initially, architects had to confirm their registration via the smart contract, which added an extra step and increased complexity. Furthermore, this step resulted in additional gas costs, posing a

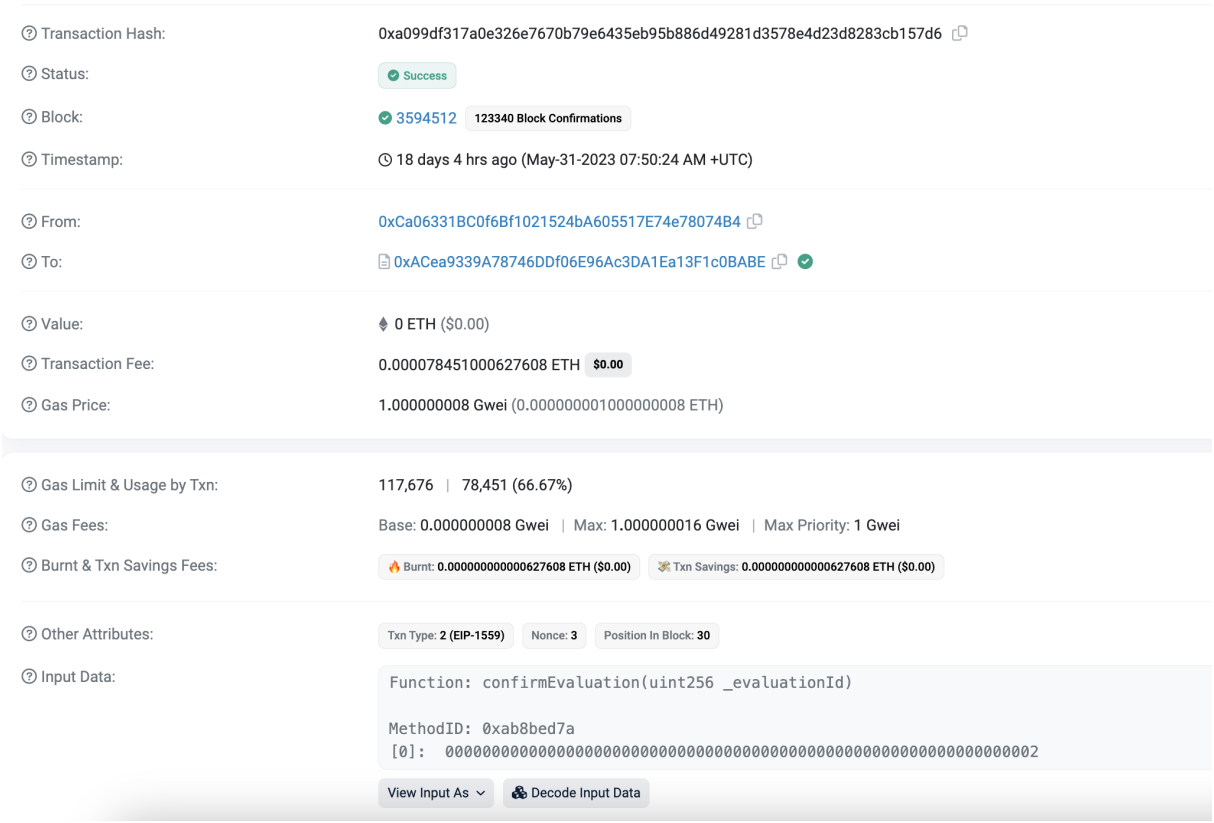


Figure 42: DAO member E confirms evaluation

financial burden on the architects. However, this function has now been consolidated into the 'confirmApplication' function, completing the registration when the requisite confirmation count is reached in the smart contract. This integration simplifies the registration process, eliminating the need for manual confirmation by the architect, and it decreases gas costs by removing the need for an extra transaction. This improvement represents an ongoing commitment to evolve and refine the DAO framework, ensuring it's user-friendly and cost-effective for its members.

3. **The confirmer of evaluation request should be architect instead of a DAO member**
To streamline the evaluation confirmation process and to balance control between the architects and the DAO members, a dual confirmation approach is proposed. In the original code, evaluation confirmation was solely the responsibility of the evaluators. This could lead to potential delays or inactivity, directly impacting the efficacy of the process. To address this, the architect requesting the evaluation will now also be involved in the confirmation process, removing the dependence on the evaluator's responsiveness and allowing for more expedited completion of the process. However, this change necessitates the provision of evaluator feedback via an off-chain system, not captured within the smart contract. Subsequently, the architect will confirm the received feedback on-chain. With such amendments, it's crucial to maintain a balance between process efficiency and control, with fairness and accuracy in the evaluation process. This dual confirmation approach empowers both parties involved, fostering a more efficient, transparent, and democratic evaluation process.

7.2.7 Iterations based on simulation test results

Reflections from the simulation test results have informed several adjustments to improve the code and workflow. The key changes are highlighted below:

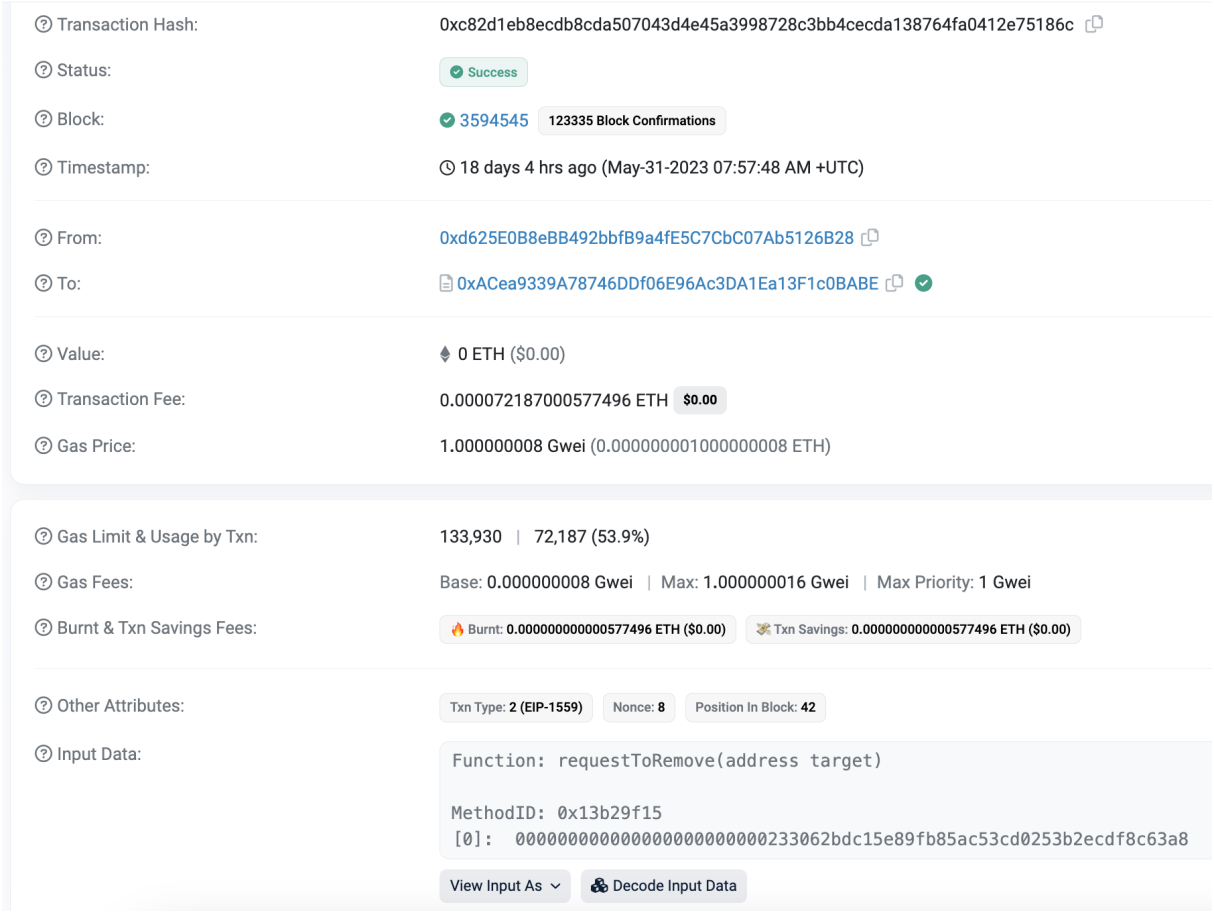


Figure 43: Removal request by architect (DAO member) A

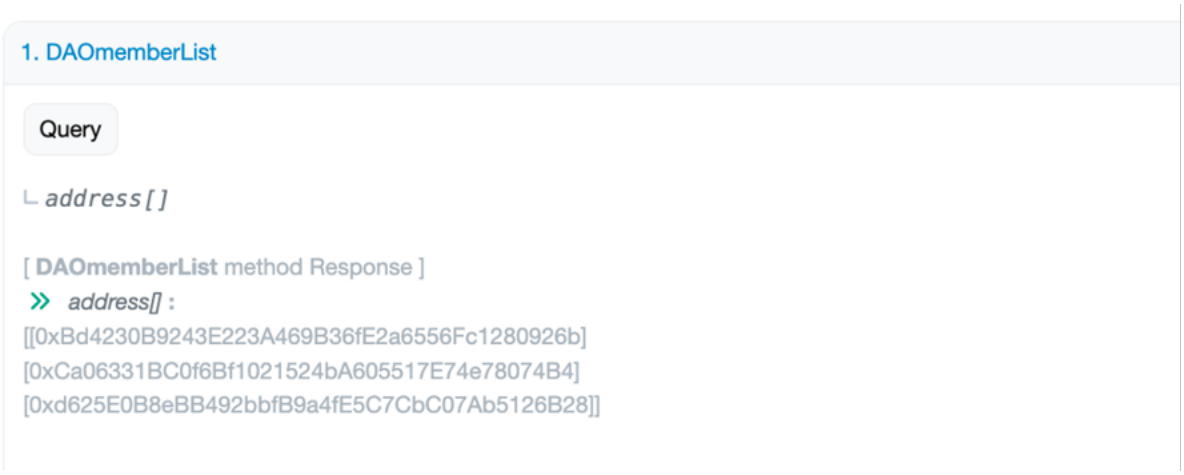


Figure 44: Confirmation of removal d

Change in Removal Request Data Structure

The data structure for removal requests has been modified (Figure 45). An array to store the addresses of selected evaluators has been added. This modification allows for enhanced tracking and management of requests. The updated structure can be seen from the Figure.

```
struct RemovalRequest {
    address target;
    uint confirmationCount;
    mapping(address ⇒ bool) confirmations;
    address[] rjudges; //get updated when removal requests are initialized
}

// Return the evaluators based on the removal request ID
function getRemovalEvaluators(
    uint requestID
) public view returns (address[] memory) {
    return removalRequests[requestID].rjudges;
}
```

Figure 45: Improvement on data structure

New Function to Check Evaluators

A function has been implemented to check who the evaluators assigned to a specific removal request are (Figure 46). This function takes the removal request id as input and returns the associated evaluators.

Removal of joinDAO function

The joinDAO function has been removed from the latest smart contract. This decision was driven by the desire to streamline the process of joining the DAO and improving the user experience and the joining process is now integrated directly into the application confirmation function, reducing the number of transactions required for a user to become a member of the DAO.

Update confirmer in 'confirmEvaluation' function

The 'confirmEvaluation' function has been restructured to ensure that the confirmation process is a dual-responsibility, involving both the architect who requested the evaluation and the evaluators. Initially, the function ensured the caller was an evaluator who hadn't confirmed the evaluation already. If these criteria were met, the confirmation was logged for the evaluator, and their rating was increased. In the updated version of this function (Figure 47), it's ensured that the caller is the architect who requested the evaluation. Then, the function proceeds to iterate through all evaluators, logging their confirmation of evaluation and incrementing their ratings. Consequently, this update bestows more control on the architect over the evaluation process, making it more balanced and efficient.

```
function confirmApplication(address applicant) public {
    require(
        applications[applicant].confirmations[msg.sender] == false,
        "Already confirmed"
    );

    // Confirm the application
    applications[applicant].confirmations[msg.sender] = true;
    applications[applicant].confirmationCount++;

    // Check if the confirmation count is 3 or more
    if (applications[applicant].confirmationCount >= 3) {
        // Add the applicant as a member of the DAO
        _members.push(payable(applicant));
        tokenId++;
        _mint(applicant, tokenId);
        _totalSupply.increment();
        memberToTokenId[applicant] = tokenId;

        // Remove the application from the mapping
        delete applications[applicant];
    }
}
```

Figure 46: Integration between joinDAO and confirmApplication

```
function confirmEvaluation(uint _evaluationId, bool calledByRequestor) public {
    require(_evaluationId == evaluationId, "Invalid evaluation id");
    Evaluation storage evaluation = evaluations[_evaluationId];
    bool isEvaluator = false;

    // If the confirmation is from the requestor, check if the sender is the requestor
    if (calledByRequestor) {
        require(evaluation.requestor == msg.sender, "Not the requestor");
    } else {
        // If the confirmation is from the evaluator, check if the sender is in the list of evaluators
        for (uint i = 0; i < evaluation.evaluators.length; i++) {
            if (evaluation.evaluators[i] == msg.sender) {
                isEvaluator = true;
                break;
            }
        }

        require(isEvaluator, "Not an evaluator");
    }

    require(
        evaluation.confirmations[msg.sender] == false,
        "Already confirmed"
    );

    // Confirm the evaluation
    evaluation.confirmations[msg.sender] = true;
    evaluation.confirmationCount++;

    // If the confirmation is from the evaluator, increase rating for evaluator
    if (!calledByRequestor) {
        ratings[msg.sender]++;
    }
}
```

Figure 47: Updated function for confirming evaluation

7.3 Expert Reviews

In order to validate the feasibility of the DAO-based evaluation system, insights and feedback were solicited from two experienced architects. Each interview was initiated with an overview of the DAO concept and its implementation in the field of architectural design. This was followed by a presentation of the evaluation model and a request for expert feedback through a set of interview questions. The specific questions and corresponding answers can be found in Appendix G, while full interview transcripts are included in an embedded file. A summary of the key insights from each expert is provided below:

7.3.1 Expert A – Previous lead architect

Expert A expressed a positive perception of the evaluation model, considering it comprehensive and largely in alignment with the expectations discussed during the previous interview, especially regarding sustainability. The potential for the model to encourage fair and objective evaluation results among architects was acknowledged through the design. However, Expert A also raised a few concerns related to the system's integration with the Decentralized Autonomous Organization, for example, potential knowledge gaps between the architects and understanding of web3 and DAO principles. As DAOs operate on blockchain technology and require an understanding of certain technical and decentralization concepts which might not be familiar to architects which might lead to difficulties in user adoption, where architects struggle to interact with the DAO due to unfamiliarity with the blockchain-based processes, interfaces, or terminology and consequently hinder the functionality of the DAO or discourage participation, thereby impacting the efficacy of the design evaluation process that the DAO is meant to facilitate. Expert A also expressed concern about potential abuse of the DAO incentive mechanism, like giving DAO token or other cryptocurrency as rewarding, which are generally implemented in organizations like DAO and use cryptocurrency tokens to motivate desired actions or deter unfavorable ones, and could potentially be implemented to the DAO in this research as well. However, If the DAO system is set to reward participants with higher points or other incentives for their evaluation activities, it could inadvertently encourage manipulative behavior, for example, participants might start "farming" points or optimizing their actions purely to gain the most rewards, rather than focusing on providing meaningful, unbiased evaluations. This could lead to a degradation of the overall quality of evaluations, as architects might focus more on exploiting the incentive system than on the integrity and value of their evaluations, which would compromise the main objective of the DAO framework.

Also, there was a suggestion to place greater emphasis on circularity in the evaluation process as it could relate to aspects such as materials sourcing, energy efficiency, or the capacity for future adaptation of the building. By emphasizing circularity, the DAO can promote more sustainable and forward-thinking designs. And to rephrase the "cultural value" criterion to "cultural context" or "cultural background" to enhance clarity. This change in terminology aims to better capture the importance of how a design interacts with and respects its cultural environment. Rather than a nebulous "value", it emphasizes the need for architects to consider and harmoniously integrate the specific cultural aspects tied to the location or intended usage of their designs.

7.3.2 Expert B – Architect with 2 years of experience

Expert B expressed his satisfaction of the evaluation system, highlighting that it met expectations by integrating comprehensive architectural design evaluation models and lauded its integration with blockchain technology. Despite this, Expert B expressed the concerns raised by Expert A about the cultural value criterion, suggesting it be revised or removed to accommodate cultural differences between architects and evaluators. Expert B also questioned the system's ability to entirely eliminate subjectivity from architectural design evaluation, considering the process inherently subjective and often a "battle of taste". Moreover, before the evaluation process begins, he mentioned that if the architect does not have a specific choice for an evaluator, and if DAO could assign random evaluators to him, he would like to see an evaluation committee consists of architects with diverse background and speciality.Nevertheless, Expert B identified transparency as a key advantage of the DAO-based evaluation model, appreciating how it could eliminate potential biases of a central authority and provide clearer insight into architects'

strengths and weaknesses.

7.4 Validation summary

The prior chapter detailed the design and development process of the DAO framework, introducing its key components and setting the stage for their validation. This validation was conducted through 2 distinct approach, encompassing both a simulation test and an expert review. These methods effectively addressed the research question, 'Can the DAO provide a comprehensive architectural design evaluation?'

The first approach consisted of a simulation test designed to validate the smart contract within the membership system. Through this method, operations such as application, confirmation, and removal were put to test in five distinct scenarios. Each scenario employed simulated participants to evaluate the smart contract's functionality, demonstrating its potential for implementation within the architectural community. This process also revealed potential areas of improvement for the registration process, user experience enhancements for architects, and the overall efficiency of smart contract operations.

Following the simulation test, an expert review was conducted to validate the evaluation system's feasibility. Experts were introduced to the concept of DAO, its integration with architectural design, and its functionality. The model was evaluated for its alignment with expectations for a new evaluation system and the established criteria were subjected to feedback from the experts. The feedback was generally positive, with architects expressing optimism about the developed design evaluation system. The integration of blockchain technology, decentralized autonomous organization principles, and the potential for fair, objective evaluations were highly commended. However, the experts also recommended improvements for the design evaluation model's criteria, expressing concerns about potential misuse, especially in relation to the criteria of cultural values.

The interpretation of these validation results confirms the DAO framework's capability to facilitate a comprehensive architectural design evaluation. Both the simulation test and expert review showcased the framework's robustness and flexibility, demonstrating its potential to reshape architectural design evaluation procedures. And the DAO framework, upon validation through simulation, displayed its feasibility for adoption in architecture, highlighting its ability to foster a democratic and transparent membership system. The evaluation system, after being subjected to expert review, was largely appreciated for its innovative approach to architectural evaluation. It provides a comprehensive, transparent, and equitable evaluation environment, empowering architects to refine their designs based on constructive, fair feedback. These validation results also suggest that the DAO framework could revolutionize how architects interact, evaluate, and evolve, breaking down traditional barriers and hierarchies in the architecture field. The framework encourages continuous learning and improvement, inviting members to engage in regular evaluations and improve their work based on peer feedback.

Overall, despite these promising prospects, it's essential to note potential risks associated with the system, as raised by the experts. The possibility of misuse, such as the exploitation of the cultural value criteria for personal gain, underlines the necessity for effective mechanisms to guard against manipulation. Hence, the DAO framework, with continued refinement and proactive measures to address potential issues, holds promise for fostering a fair, transparent, and innovative architectural design community.

Chapter 8

Conclusion and discussion

The previous chapter has successfully validated the proposed DAO framework's functionalities, demonstrating its potential in facilitating fair and objective architectural design evaluations among architects. And this chapter will encapsulate the entire research journey by answering research questions, discussing the limitations of the current research, and outlines the potential areas for future research.

8.1 Conclusion

This research aims to solve the problem from architects, 'how to get objective architectural design evaluation and feedback from other professionals in a more accessible way?' by applying the concept of Decentralized Autonomous Organization (DAO) onto the field of architectural design. The problems became clear after a number of literature research and interviews with architects as follows:

1. Architects have limited chances to get evaluation feedback since their graduation.
2. Architects find it hard to get design feedback from other architects without any bias.
3. The existing architectural design evaluation approach covers criteria that architects do not fully agree on.

The identification of problems helped to define the main research question:

How to design a Decentralized Autonomous Organization (DAO) framework that provides a comprehensive architectural design evaluation system to enable objective evaluation results and feedback opportunities?

And to fully answer the main research question, it has been broken down into several sub-question in previous chapters. These sub-questions have served as a guideline for the structure of this research, and their answers are organized in the following paragraphs :

Research question 1 : Why is an extensive architectural design evaluation required and necessary for architects?
As suggested by the research by [25], the design evaluation plays a significant role in architects' education as it promotes a deeper understanding to architectural design and foster the culture of continuous learning and skills enhancement. However, several interviewed architects revealed that the design evaluation is no longer valued in working environment anymore and they received much fewer design feedback since they graduated.

Beyond that, most interviewed architects and research by Dounas, Lombardi, et al. [21] revealed perceived bias in design evaluations, for example, when it comes to design evaluation, the results are generally

influenced by subjective factors, including strong personal tastes, financial factors, undermining the objectivity of the evaluation process. Moreover, In today's working environment, it appears that the dominant evaluation approach overly prioritizes budget, profit, and project deadlines. While these factors are undoubtedly important, the architects interviewed did not fully agree with this limited focus. They expressed a need for a more comprehensive evaluation approach that adequately considers the unique and intrinsic value of their designs.

Furthermore, a few architects also emphasized the need for a dynamic industry standard for design evaluation, rather than a static one. They believe that as architectural design evolves, so should the standards and criteria for evaluation, ensuring relevance and applicability in an ever-changing field. This sentiment resonates with the foundational concept of continuous learning and skills enhancement in architecture.

Research question 2 : Why should a DAO be a solution rather than a traditional organization?
This research question can be answered by the unique advantages of DAO compared with traditional organizations, making it an ideal solution in the context of architectural design evaluation.

The transparency provided by DAOs mainly lies in the execution of operations. Each action within the DAO is recorded on the blockchain, offering a transparent, immutable history of transactions. This feature ensures that all actions are accountable and verifiable, creating a trustworthy environment within the organization [72]. In the context of architectural design evaluation, the evaluation criteria are not executed on the blockchain, but they are publicly transparent. This means all participants understand the foundation on which designs are evaluated, adding another layer of transparency to the process.

Another benefit of DAOs is their decentralized nature, which means there's no central authority. In architectural design, this decentralization ensures a more fair and objective evaluation process [72]. Any participating architects within the DAO can contribute to the evaluation process, fostering a more democratic environment that's not dominated by a few key decision-makers.

Lastly, the autonomous feature of DAOs makes them especially suited to architectural design evaluation. DAOs are run by their participants – in this instance, architects which means those with expertise and vested interest in the field are the ones contributing to the evaluation process. This direct involvement of professionals ensures evaluations are relevant, as they're conducted by those who are familiar and experienced with the field.

Research question 3 : What features should be expected by architects from the DAO?
The answer to this research question lies within the design of the proposed DAO framework, which incorporates two essential components designed to meet architects' expectations to an organization designed for extensive and objective design evaluation.

Firstly, a smart contract-powered membership system is designed to ensure that only qualified architects are granted access to join the DAO. The uniqueness of this system lies in its approach to membership validation: every application is reviewed by three randomly selected DAO members. This process not only verifies the qualification of potential members but also embodies the decentralized and democratic nature of the DAO.

Secondly, a comprehensive evaluation system developed through integrating and adapting from existing architectural design evaluation models to fit within the DAO framework. The selection of evaluation criteria is guided by the suggestions from interviewed architects, ensuring that the system reflects real-world expectations and professional standards.

Research question 4 : Can the DAO guarantee the quality of architectural evaluations?
The research question can be answered by the designed mechanism of membership system. To ensure the quality of evaluation results given by DAO members, the DAO will only grant membership to those who are qualified to give feedback. The qualification of applicants will only be determined by existing DAO members.

The smart contract of DAO membership was designed to make sure the expected scenario will happen by every time an architects initiates an application to join the DAO through smart contract, the smart

contract will foward this application to 3 random DAO members and wait for them to approve the application. In the context of this research, the choice to have applications reviewed by three members is a balance between ensuring a thorough review and maintaining efficiency in the approval process. The diversity of thoughts and tastes can be balanced for a fair judgement, mitigating the risk of a singular biased decision. At the same time, it is a small enough number to keep the process quick and efficient, ensuring that potential new members are not kept waiting for an extended period, which might be the case if the application had to be reviewed by a larger number of members. However, the number of judges should not be fixed in the further development of DAO.

On the other hand, by not having a fixed group or individuals responsible for reviewing applications, the process avoids the potential for bias or undue influence that may occur in a more centralized system. It also ensures that every member of the DAO has an equal opportunity to participate in the decision-making process, upholding the democratic nature of the DAO.

More importantly, the validation results also indicates that the designed mechanism of the smart contract has proven to be effective through simulation tests. These tests validated the functionality of the smart contract, demonstrating its ability to accurately implement the process as designed – forwarding applications to random members, waiting for their approval, and managing the DAO's membership. This successful validation not only confirms the smart contract's operational capability, but it also strengthens the confidence in the reliability and efficiency of this decentralized and autonomous system for architectural design evaluation.

Research question 5 : Can the DAO provide comprehensive architectural design evaluation?
The research question can be answered by the validation results, expert reviews of design evaluation system. The expert reviews collectively recognized the ability of the DAO to provide comprehensive architectural design evaluation, acknowledging its alignment with their expectations and its strong emphasis on sustainability. Both experts also appreciated the comprehensive nature of the evaluation model and its integration with blockchain technology, recognizing the transparency this brings and its potential to mitigate bias.

However, the experts highlighted areas for improvement. One shared concern was the "cultural value" criterion, which was suggested to be rephrased for clarity or altered to better accommodate cultural variations. Additionally, they acknowledged the subjective nature of architectural design evaluation, noting that it may be challenging to entirely eliminate subjectivity, and that there's potential for the system to be "gamed" to earn higher incentives.

Further, they expressed a desire for a more diverse committee of evaluators, particularly in instances where an architect has no specific evaluator preference. This would ensure a well-rounded and balanced evaluation process, mirroring the decentralized and diverse nature of the DAO itself. Despite these points for consideration, both experts expressed overall satisfaction and optimism about the DAO's ability to provide a comprehensive architectural design evaluation.

Main research question: **How to design a Decentralized Autonomous Organization (DAO) framework that provides a comprehensive architectural design evaluation system to enable objective evaluation results and feedback opportunities?**

The answers to previous sub-research questions have proved the validity of this research and the potential of Decentralized Autonomous Organizations (DAO), along with their associated technologies, to promote more efficient and impartial architectural design evaluations .Consequently, this paves the way to address the main research question of this study: "How to design a Decentralized Autonomous Organization (DAO) framework that provides a comprehensive architectural design evaluation system to enable objective evaluation results and feedback opportunities?" In the initial stages, the research identified the main challenges and stakeholders. Architects, since their graduation, face a lack of opportunities to receive evaluative feedback. Moreover, when architects do receive feedback from their peers, bias often distorts its value. Another identified issue is the prevailing architectural design evaluation approach, which covers criteria that do not universally resonate with architects.

The research then pivoted to identifying a potential solution to these challenges, which was found in the form of the Decentralized Autonomous Organization (DAO). DAOs possess several distinctive character-

istics that makes it functional in architectural design field. These include a decentralized membership system, a shared mission among members, a transparent execution process, the absence of a central authority, and most crucially, the system is run autonomously by architects.

This solution was then implemented, employing two key components. The first was a decentralized membership system. This system ensures that architects participate in the membership validation process, creating a fair and objective selection mechanism. The second component is a comprehensive architectural design evaluation system. This system integrates and adapts from existing architectural design evaluation models to provide a thorough and objective assessment of designs. This implementation should not only address the identified problems but also offer new opportunities and advantages for the architectural community.

In summary, the framework designed and developed through this research aims to lead several expected results that would significantly benefit the architectural community:

1. Opportunities for Design Evaluations: By participating in the DAO, architects can consistently receive feedback on their designs, fostering an environment of continual improvement and learning.
2. Objective Feedback on Designs: The use of comprehensive architectural design evaluation system ensures that feedback is grounded in objective criteria, thereby helping to eliminate biases and offer more constructive criticism.
3. Continuous Learning Opportunities: With constant feedback from a variety of architects, members would get a chance to continually learn and improve their designs, thus fostering a culture of continuous learning and skill enhancement.
4. Enhanced Evaluation Transparency: The DAO framework, built on blockchain technology, ensures that all evaluation procedures and results are transparent, traceable, and verifiable. This transparency enhances trust and confidence in the evaluation process.
5. Inclusive Decision Making: As a decentralized system, all member architects in the DAO have an equal say in decision-making processes. This encourages a democratic and inclusive environment where all voices are heard and valued.
6. Professional Networking: Participation in the DAO provides architects with opportunities to connect with other professionals in their field, fostering collaboration and the exchange of ideas.

Overall, by addressing the identified issues in architectural design field and creating a DAO framework with the proposed features, this research has designed a framework that is expected to bring significant improvements to the process of architectural design evaluation. This not only enriches the professional development of architects but also has the potential to catalyze a transformative shift in the field of architectural design, opening new avenues of innovation, collaboration, and excellence.

8.2 Threats to validity

1. Internal validity: This research sought to design a comprehensive DAO framework that could cater to the unique needs of the architectural industry. However, due to the wide scope of components, elements, and requirements that a fully operational DAO should ideally be equipped with, it was not feasible to address all of these within the scope of the current research. While the developed framework is functional and effective, it may not encompass every component that might prove beneficial or necessary in real-world applications. Further work is needed to refine and expand the DAO framework to completely address all potential needs and circumstances.
2. Evaluation Criteria: One of the major aims of this research was to establish a functional and objective evaluation criterion for architectural designs. Despite incorporating widely recognized models like BREEAM and CB'23 circularity design and other well-validated research models, the inherent limitations of these models pose a challenge. While these models are comprehensive, they may not cover all the aspects of sustainability and circularity. Furthermore, as these models

are continually updated, there is a need to keep the DAO system adaptable to changes in these evaluation criteria.

3. Untestified DAO Implementation: The proposed DAO framework, while theoretically sound and promising, is still untested in the practical world of the architectural industry. The real-world complexities, user experiences, and the level of acceptance of such a DAO model may vary from the expectations. The shift from traditional centralized systems to this decentralized model may face resistance, which could hinder its widespread implementation.

4. Subjectivity Elimination: Although reducing subjectivity in architectural design evaluations is one of the primary objectives of this DAO framework, it is important to acknowledge that no system can fully eliminate bias or subjectivity, as mentioned in several interviews with architects. Evaluating designs, even with the most objective and comprehensive evaluation models, still carries subjective elements. Therefore, while the DAO system significantly mitigates bias, complete elimination remains a challenge. As such, the results should always be interpreted with an understanding of this inherent limitation.

8.3 Discussion on risks of the framework

Despite the affirmation of the DAO methodology's effectiveness in facilitating design evaluation in the preceding chapter, potential risks related to the smart contract and evaluation system persist, that worth in-depth discussion.

8.3.1 Exploitation of Smart Contract

Smart contracts, while serving as a crucial component in establishing and enforcing the rules within the DAO, are not immune to exploitation or misuse. Their autonomous, self-executing nature brings a unique set of risks and vulnerabilities.

One such risk pertains to the immutable nature of smart contracts. Once deployed, they cannot be altered. If a flaw or vulnerability exists in the contract code, it can lead to significant consequences, such as the loss of funds or the collapse of the DAO itself, as seen in the infamous DAO hack in 2016.

Moreover, the evaluation process within the DAO, facilitated by the smart contract, may be susceptible to collusion or Sybil attacks. For instance, an individual could create multiple addresses to unduly influence the outcome of evaluations or manipulate membership processes. Additionally, smart contracts rely heavily on the input data they receive, often referred to as the 'oracle problem.' If the data source providing information to the contract is manipulated, the contract will execute based on this manipulated data, leading to incorrect and potentially damaging outcomes. Also, the potential for gas price manipulation exists. As Ethereum transactions require 'gas' to execute, participants with higher resources could potentially manipulate transaction ordering or delay others' transactions by bidding higher gas prices.

Therefore, mitigating these risks requires careful, security-focused smart contract design, rigorous auditing and testing, and potential implementation of governance mechanisms for upgradeability. However, these measures cannot entirely eliminate the inherent risks, necessitating ongoing vigilance and adaptive strategies[72, 28, 49].

In addition to these inherent vulnerabilities, the smart contract and the DAO itself may also face threats from deliberate exploitation attempts. Participants with malicious intent might attempt to overwhelm the system by spamming the smart contract with a large volume of requests. Such actions could lead to network congestion, delayed transactions, and inflated gas prices, disrupting the smooth operation of the DAO and the evaluation process.

To protect the integrity and security of the DAO and its smart contract system, it is suggested and crucial to establish and enforce robust security regulations. Such regulations could include:

- The implementation of rate-limiting measures to prevent spamming and system overload.
- Regularly scheduled audits and updates to the smart contract to fix known vulnerabilities and improve security features.
- The development of a transparent and fair governance system to handle disputes, report vulnerabilities, and suggest improvements to the smart contract system.
- The use of secure and reliable data sources to mitigate the 'oracle problem.'
- The enforcement of strict identity verification measures to prevent Sybil attacks.

These measures, based on implementation of existing DAOs, while requiring continual monitoring and improvement, can greatly enhance the security and resilience of the DAO's smart contract system. They underscore the importance of proactive security practices in the face of evolving threats and the complex nature of blockchain technology.

However, it is important to note that while these measures can significantly reduce the risk of exploitation and misuse, they cannot entirely eliminate them. As such, a culture of security awareness and ethical conduct among DAO members is equally essential to safeguard the integrity of the evaluation process and the DAO itself.

8.3.2 Evaluation Subjectivity

During the interviews, architects emphasized that subjectivity plays an integral role in the architectural design evaluation process. An evaluation often involves judgments influenced by personal tastes, professional backgrounds, and the unique way architects perceive design. Take architectural aesthetics as an example. It's subject to personal interpretation. A design may be viewed as innovative and appealing by one architect, while another might find it unattractive or out of place. Other factors like functionality and context sensitivity can also be seen differently amongst architects.

While the DAO framework and the smart contract system provide a structured means of conducting evaluations, they cannot remove these subjective elements. An architect's evaluation will inevitably be influenced by their design philosophies, past experiences, and personal perspectives. Additionally, factors such as cultural background, architectural style preference, and unique vision for sustainability further add to the subjectivity of the evaluation process. These factors not only influence the aesthetic evaluation of a design but also its perceived functionality, contextual integration, and environmental impact. The existence of subjectivity underlines the importance of a diverse membership within the DAO, where different perspectives contribute to a more comprehensive evaluation. It also emphasizes the need for DAO members to act with professional integrity and respect for different opinions, ensuring a balanced and fair evaluation process.

On the other hand, While it's undeniable that subjectivity forms an integral part of the architectural design evaluation, efforts can be made to mitigate its influence to maintain objectivity and fairness in the assessment process. One such effort lies in the configuration of the DAO's smart contract system.

The smart contract currently allows architects to express a preference for certain evaluators. Although this feature was intended to create a more personalized evaluation process, it may inadvertently introduce a bias in the evaluation. An architect might favor evaluators who share their design philosophies or who have previously given positive feedback to their designs. This could potentially skew the evaluation results and compromise the objectivity of the process.

To address this concern, it is proposed that the evaluator selection process in the smart contract be made entirely anonymous. Removing the ability for architects to choose their evaluators helps eliminate potential biases. It also ensures that all architectural designs are evaluated on their merits alone and not on the rapport between the architect and the evaluator.

In this setup, when an architect submits a design for evaluation, the smart contract system would randomly assign evaluators from the DAO membership. This process not only enhances the objectivity of

the evaluations but also diversifies the feedback, as designs would be assessed by different evaluators each time.

Anonymizing the evaluator selection process also helps ensure that a variety of perspectives are considered in each evaluation. Given that DAO members come from different professional backgrounds, have varied design philosophies, and unique visions for sustainability, a random selection of evaluators would enrich the evaluation process by incorporating a broad range of insights.

Overall, this proposed modification to the DAO smart contract, in conjunction with the continued emphasis on professional integrity and respect for different opinions, aims to further strengthen the evaluation process. It ensures a fairer, more balanced, and comprehensive assessment of architectural designs, fostering continuous improvement and innovation in the field.

8.4 Recommendation to future research

Based on the summarized limitation of the research, a few recommendations to future research are given below:

1. Expansion of DAO Framework: While this research laid the groundwork for a DAO framework targeted towards architectural design evaluations, there is much room for expansion. Future research could focus on incorporating additional components into the DAO framework, such as tokenomics, governance mechanisms, voting systems, and more. As the number of members or the complexity of projects increases, it would be necessary to ensure that the DAO system could efficiently manage and accommodate this growth with wider functionalities. This would create a more robust and comprehensive system that could further empower architects and enhance the design evaluation process.
2. Legal and Regulatory Consideration: As DAOs represent a relatively new organizational structure, particularly in fields like architecture, the legal and regulatory implications of these systems are not yet fully understood. Future research should aim to explore these aspects, identifying potential legal obstacles or requirements for operating a DAO within the architectural sector. This would not only ensure the compliance of DAOs but also contribute to the broader understanding of DAOs within legal contexts.
3. Sustainability of DAOs: DAOs depend on active and engaged participation to function effectively. Future research could delve into this area, exploring how tokens can be used to encourage active participation, contribute to decisions, or reward contributions. Simultaneously, the incentive structures within DAOs should be examined to ensure they encourage long-term commitment and value creation rather than short-term gains. This research direction would provide insights that could contribute significantly to the sustainability and long-term success of DAOs in the architectural sector.
4. Training and Education: The adoption of DAOs in the architectural sector is likely to require some level of familiarity with blockchain technology. There is an apparent need to equip architects with the knowledge necessary to interact with the DAO system and its underneath blockchain technology. Future research should focus on creating dedicated educational programs and training modules that demystify the DAO framework and blockchain technology. This could encompass foundational knowledge of blockchain, the operation of DAOs, smart contracts, tokenomics, and the use of cryptocurrency. Providing such education and training can help architects become active, informed participants in DAOs, and aid in the smooth integration and adoption of the DAO framework within the architectural community. Consequently, this will lead to a more inclusive environment where all members can contribute effectively to the decision-making process.
5. Reputation system: The current reputation system primarily operates on the basis of confirmation of design evaluations, allowing evaluators to accrue reputation points for their contributions. However, the system could benefit from a more nuanced approach that accounts for the quality and integrity of evaluations, and fosters a culture of accountability. For instance, architects should have the option to contest evaluation results if they believe that their design has been unfairly or inadequately

assessed. If the DAO, through a fair and transparent review process, validates these complaints, the evaluator's reputation points could be adjusted downwards to reflect their subpar evaluation. This change would not only enhance the reliability and fairness of the evaluation process but also incentivize evaluators to deliver high-quality, thorough evaluations consistently. It could also foster a sense of mutual respect and understanding within the DAO, as members acknowledge and learn from their mistakes. Future research could delve into the development of such a dynamic and fair reputation system, exploring the best methods for handling disputes, adjusting reputation points, and encouraging quality evaluations.

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Appendix A

Logs of interview A

Interviewee : Architect A

Interviewer : Zhijiang Chen

Date : Mar 24th, 2023

Interviewee experience : Previous lead architect

Q: As an architect, how do you evaluate the success or quality of your designs?

A: Well, in practice, it's mostly evaluated based on factors such as profitability, staying within budget, and meeting deadlines. The aesthetics side is more subjective and can vary depending on individual preferences. Another important aspect is evaluating the functionality of the design, considering factors like flow, lighting, ventilation, and whether it fulfills its intended purpose.

Q: Do you think the acceptance from your colleagues means/stands for the success of your design?

A: It's pleasant to receive compliments from colleagues, and it can be motivating. However, in our field, we are often too busy to give extensive feedback to each other. During studies, we have more time to evaluate each other's work and provide compliments, which can be motivating. But overall, colleague acceptance alone does not solely determine the success of a design.

Q: What are the components/aspects do you care about when it comes to evaluating your architectural designs?

A: I primarily consider the functional requirements, such as whether the design fulfills its intended purpose effectively. Additionally, I take into account aesthetics, although it is subjective. Evaluating the overall benefit and contribution to the city and people is also important to me.

Q: What is the process of the existing evaluation approach of architectural designs?

A: In my experience, there hasn't been a dedicated evaluation phase after completing a project. The project is often forgotten or left in the company's portfolio. Feedback and criticism are typically focused on marketing and presenting the project to investors and clients. Professional critics or colleagues from the same field can provide valuable feedback to improve future designs.

Q: Who are the participants of the evaluation process of your architectural designs?

A: Ideally, professional critics with architectural knowledge and expertise should be involved in the evaluation process. However, in reality, evaluations often involve journalists, marketing personnel, and colleagues from other companies in the same field.

Q: Are there any colleagues from other departments/participants from external organizations?

A: Yes, colleagues from other departments within the same organization and participants from external organizations, such as journalists or marketing personnel, can be involved in the evaluation process.

Q: Are you comfortable with people from external organizations evaluating your designs?

A: I am comfortable with people from external organizations evaluating my designs as long as they have relevant knowledge and expertise in the architectural field. However, if the evaluation is done by someone without proper architectural analysis skills, such as a copywriter, I would be less comfortable with their assessment.

Q: Are you satisfied with the existing approach of architectural design evaluation?

A: No, I am not satisfied with the existing approach of architectural design evaluation, especially in the organizations I have worked for. The focus is often heavily on numbers and financial aspects, neglecting the importance of functionality and the human factor. Evaluations based solely on profitability and statistics can lead to designs that lack consideration for comfort and overall benefits.

Q: Have you ever encountered situations where you felt that the evaluation of your architectural designs was subjective or biased?

A: Yes, there have been instances where I felt the evaluation of my architectural designs was subjective or biased. The main biases often stem from clients who are primarily focused on numbers and statistics, disregarding the human factor and the comfort of the users.

Q: What do you think are the limitations of current approaches to realize the objective value of architectural design?

A: The limitations of current approaches lie in the excessive focus on profitability and financial aspects, which can overshadow the importance of functionality and the overall benefits of the design. Evaluations that are purely driven by numbers and statistics often fail to capture the true value of architectural designs.

Q: Are the limitations or problems in personal or system level?

A: The limitations and problems are present at both personal and system levels. On a personal level, biases and subjective preferences can influence evaluations. At a system level, the emphasis on financial aspects and profitability can overshadow other important factors, leading to a lack of objective evaluation.

Q: What evaluation approach are you expecting in the future when it comes to evaluating your designs?

A: In the future, I would like to see a more comprehensive and holistic evaluation approach. It should focus on the overall benefits of the design, including the comfort and well-being of the users, as well as its contribution to the city and society.

Q: What aspects should it focus on? What components/criteria should it include?

A: The future evaluation approach should focus on aspects such as functionality, aesthetics, sustainability, user comfort, and the overall benefit to the city and society. It should include criteria that evaluate the design's effectiveness in fulfilling its purpose, creating a positive user experience, and contributing to the well-being of the community.

Q: Do you want the IP of your architectural design to be protected through public licensing?

A: While it would be nice to have intellectual property protection for architectural designs, it can be challenging, especially in team-based projects. Often, designs are a collaborative effort, making it difficult to determine individual ownership. Additionally, in some cases, it may be acceptable for designs to be

used for educational purposes or nonprofit initiatives without requiring permission from the original designer.

Appendix B

Logs of interview B

Interviewee : Architect B

Interviewer : Zhijiang Chen

Date : March 25th, 2023

Interviewee experience as architects : 2 years of experience being an architect, worked for multiple large and medium sized project

Q: As an architect, how do you evaluate the success or quality of your designs?

B: Well, in practice, it's mostly evaluated based on factors such as profitability, staying within budget, and meeting deadlines. The aesthetics side is more subjective and can vary depending on individual preferences. Another important aspect is evaluating the functionality of the design, considering factors like flow, lighting, ventilation, and whether it fulfills its intended purpose.

Q: Do you think the acceptance from your colleagues means/stands for the success of your design?

B: It's pleasant to receive compliments from colleagues, and it can be motivating. However, in our field, we are often too busy to give extensive feedback to each other. During studies, we have more time to evaluate each other's work and provide compliments, which can be motivating. But overall, colleague acceptance alone does not solely determine the success of a design.

Q: What are the components/aspects do you care about when it comes to evaluating your architectural designs?

B: I primarily consider the functional requirements, such as whether the design fulfills its intended purpose effectively. Additionally, I take into account aesthetics, although it is subjective. Evaluating the overall benefit and contribution to the city and people is also important to me.

Q: What is the process of the existing evaluation approach of architectural designs?

B: In my experience, there hasn't been a dedicated evaluation phase after completing a project. The project is often forgotten or left in the company's portfolio. Feedback and criticism are typically focused on marketing and presenting the project to investors and clients. Professional critics or colleagues from the same field can provide valuable feedback to improve future designs.

Q: Who are the participants of the evaluation process of your architectural designs?

B: Ideally, professional critics with architectural knowledge and expertise should be involved in the evaluation process. However, in reality, evaluations often involve journalists, marketing personnel, and colleagues from other companies in the same field.

Q: Are there any colleagues from other departments/participants from external organizations?

B: Yes, colleagues from other departments within the same organization and participants from external organizations, such as journalists or marketing personnel, can be involved in the evaluation process.

Q: Are you comfortable with people from external organizations evaluating your designs?

B: I am comfortable with people from external organizations evaluating my designs as long as they have relevant knowledge and expertise in the architectural field. However, if the evaluation is done by someone without proper architectural analysis skills, such as a copywriter, I would be less comfortable with their assessment.

Q: Are you satisfied with the existing approach of architectural design evaluation?

B: No, I am not satisfied with the existing approach of architectural design evaluation, especially in the organizations I have worked for. The focus is often heavily on numbers and financial aspects, neglecting the importance of functionality and the human factor. Evaluations based solely on profitability and statistics can lead to designs that lack consideration for comfort and overall benefits.

Q: Have you ever encountered situations where you felt that the evaluation of your architectural designs was subjective or biased?

B: Yes, there have been instances where I felt the evaluation of my architectural designs was subjective or biased. The main biases often stem from clients who are primarily focused on numbers and statistics, disregarding the human factor and the comfort of the users.

Q: What do you think are the limitations of current approaches to realize the objective value of architectural design?

B: The limitations of current approaches lie in the excessive focus on profitability and financial aspects, which can overshadow the importance of functionality and the overall benefits of the design. Evaluations that are purely driven by numbers and statistics often fail to capture the true value of architectural designs.

Q: Are the limitations or problems in personal or system level?

B: The limitations and problems are present at both personal and system levels. On a personal level, biases and subjective preferences can influence evaluations. At a system level, the emphasis on financial aspects and profitability can overshadow other important factors, leading to a lack of objective evaluation.

Q: What evaluation approach are you expecting in the future when it comes to evaluating your designs?

B: In the future, I would like to see a more comprehensive and holistic evaluation approach. It should focus on the overall benefits of the design, including the comfort and well-being of the users, as well as its contribution to the city and society.

Q: What aspects should it focus on? What components/criteria should it include?

B: The future evaluation approach should focus on aspects such as functionality, aesthetics, sustainability, user comfort, and the overall benefit to the city and society. It should include criteria that evaluate the design's effectiveness in fulfilling its purpose, creating a positive user experience, and contributing to the well-being of the community.

Q: Do you want the IP of your architectural design to be protected through public licensing?

B: While it would be nice to have intellectual property protection for architectural designs, it can be challenging, especially in team-based projects. Often, designs are a collaborative effort, making it difficult to determine individual ownership. Additionally, in some cases, it may be acceptable for designs to be

used for educational purposes or nonprofit initiatives without requiring permission from the original designer.

Appendix C

Logs of interview C

Interviewee : Architect C

Interviewer : Zhijiang Chen

Date : March 30th, 2023

Interviewee experience : Previous architect intern

Q: As a student or as an architect, how do you evaluate the success or quality of your designs?

C: It depends on the goals of the project. I consider the functionality, aesthetics, and construction ability of the design. Meeting the set goals and objectives is important for evaluating the success of the design.

Q: Do you think the acceptance or compliments from your colleagues count as a factor of success for your design?

C: Compliments from colleagues are always well accepted and can be motivating. It is nice to receive positive feedback from peers, as it signifies that the project is appreciated.

Q: Can you describe the process of the existing evaluation approach in your architectural design process?

C: The evaluation process often involves self-assessment, feedback from colleagues, and consideration of client requirements. The functionality, aesthetics, and construction ability of the design are evaluated.

Q: Who are the participants in the evaluation process of your architectural designs?

C: The participants in the evaluation process include myself, colleagues who have worked on the project, the client, and sometimes the municipality or other external organizations.

Q: Are you comfortable with people from external organizations evaluating your designs?

C: Yes, I am comfortable with evaluations from experienced individuals in the architecture field. Their feedback can be challenging and exciting, providing a different perspective.

Q: Are you satisfied with the existing approach to architectural design evaluation?

C: It depends on the context and the professor involved. Architecture design evaluation can be subjective, but I am open to constructive critiques. I believe it is important to have different perspectives.

Q: Have you ever encountered situations where you felt that the evaluation of your architectural designs was subjective or biased?

C: Yes, cultural factors and different design contexts can influence subjective evaluations. Evaluations can vary based on the standards and objectives of different cultures or locations.

Q: What limitations or problems do you see in the current approaches to realize the objective value of architectural design?

C: Objective evaluation in architecture is challenging due to the subjective nature of the field. Evaluations can be influenced by cultural factors, different design contexts, and individual perspectives.

Q: What evaluation approach do you expect in the future when it comes to evaluating your designs?

C: I expect a greater emphasis on storytelling and presentation techniques. The use of 3D programs, renders, and other visual elements can enhance the evaluation process and help convey the design intent.

Q: Do you want the intellectual property of your architectural design to be protected through public licensing?

C: Yes, I believe it is important to protect the intellectual property of architectural designs. Having a licensing system in place can help ensure proper recognition and prevent unauthorized use of designs.

Appendix D

Logs of interview D

Interviewee : Architect D

Interviewer : Zhijiang Chen

Date : Marchh 30, 2023

Interviewee experience : 5 years of experience being an architect, worked for multiple large-sized project in China

Q: As an architect, how do you evaluate the success or quality of your designs?

D: As for me, architecture is a combination of technology and art. Evaluating the success or quality of design involves two aspects. Firstly, the architecture design should be pragmatic and meet the needs of society, as well as consider cultural heritage. Secondly, I focus on the artistic aspects of architecture, aiming to create innovative and unconventional designs that stand out in the urban environment. Understanding the historical and cultural values of architecture is also crucial in achieving spiritual success or quality.

Q: Do you think the acceptance from your colleagues means/stands for the success of your design?

D: While the acceptance from colleagues does matter, it is not the sole determinant of success. Architecture design involves collaboration and discussions with other architects, as their expertise in different areas complements my own. Architects cannot possess all the knowledge in various aspects of design, such as construction, technical details, materials, interior, and landscape design. Therefore, the opinions and recommendations from colleagues and consultants are valuable in enhancing the overall quality of the design.

Q: What components/aspects do you care about when it comes to evaluating your architectural designs?

D: When evaluating architectural designs, I consider the functional requirements, objective value, and novelty compared to previous designs. It is essential for the design to meet the basic needs of users and exhibit innovative qualities. Additionally, I value the cultural and historical values embedded in the design, as well as the impact it has on the urban environment. Overall, a successful design should strike a balance between functionality, creativity, and the preservation of cultural and historical elements.

Q: What is the process of the existing evaluation approach of architectural designs?

D: The evaluation process of architectural designs starts with considering the form and shape of beauty. Then, the reasoning behind the design concept is explained, highlighting aspects like sustainability or the use of passive regulations. The evaluation focuses on whether the design meets the basic needs of the users. Large-scale projects often involve competitions organized by clients or governments to select the

most suitable design.

Q: Who are the participants of the evaluation process of your architectural designs?

D: The evaluation process involves various participants. The main ones include the team leader and colleagues within the architectural firm. Additionally, clients play a significant role in evaluating the designs as they have the final say. The evaluation process can also include external consultants who provide specialized knowledge in areas such as structure, curtain wall, climate, and other relevant disciplines.

Q: Are you comfortable with people from external organizations evaluating your designs?

D: Yes, I am comfortable with external organizations, especially those with professional architecture experience, evaluating my designs. Their input and expertise can bring value to the project, contributing to its overall improvement and quality. Collaboration with external organizations and consultants is often necessary to incorporate diverse knowledge and perspectives into the design process.

Q: Are you satisfied with the existing approach of architectural design evaluation?

D: I find the existing approach of architectural design evaluation mostly satisfactory. The satisfaction level can vary depending on the clients and the firm I am working with. When working with reputable and influential firms, there is a higher chance to persuade clients and have more control over the design outcome. However, the satisfaction also depends on the type of project and the level of value assigned by clients to architectural design.

Q: Have you ever encountered situations where you felt that the evaluation of your architectural designs was subjective or biased?

D: Yes, there have been instances where I felt that the evaluation of my architectural designs was subjective or biased. Architectural design is dynamic and constantly evolving, which may lead to different interpretations and opinions. Subjectivity can arise from personal preferences or limited understanding of the design concept. Biases can stem from clients' predetermined expectations or the hierarchy within the organization.

Q: What do you think are the limitations of the current approaches to realizing the objective value of architectural design?

D: The current approaches to evaluating architectural design have limitations. Firstly, the subjective nature of design and the varying interpretations of its value make it challenging to establish objective standards. Secondly, personal preferences and biases can influence the evaluation process, potentially overshadowing the objective aspects of the design. Thirdly, the dynamic nature of architectural design makes it difficult to define a fixed set of criteria for determining objective value.

Q: What evaluation approach are you expecting in the future when it comes to evaluating your designs?

D: In the future, I hope to see an evaluation approach that places more emphasis on cultural and historical aspects. Evaluations should focus on the consciousness and spiritual value embedded in the design, along with considerations of environmental sustainability. The future approach should also allow for dynamic and evolving standards that reflect the ever-changing nature of architectural design.

Q: What aspects should the future evaluation approach focus on?

D: The future evaluation approach should focus on the cultural and historical values associated with architectural designs. It should also emphasize the consciousness and spirituality aspects of the design. Additionally, sustainability and environmental considerations should be integral components of the evaluation process.

Q: What components/criteria should the future evaluation approach include?

D: The future evaluation approach should include components such as the cultural and historical relevance of the design, its impact on the urban environment, its sustainability features, and its ability to meet the

functional needs of users. Criteria related to the innovative qualities, uniqueness, and artistic expression should also be considered.

Q: Do you want the intellectual property of your architectural design to be protected through public licensing?

D: Personally, I believe that intellectual property protection in the field of architectural design is challenging due to the nature of ideas and shared knowledge. While it may be difficult to enforce strict protection, certain technical details and solutions could be protected through public licensing. However, I also believe in the open exchange of ideas and the evolution of architectural design, as long as it does not involve blatant copying.

Appendix E

Logs of interview E

Interviewee : Architect E

Interviewer : Zhijiang Chen

Date : April 3rd, 2023

Interviewee experience : 2 years of experience being an architect, worked for multiple small to medium-sized project

Q: How do you as an architect evaluate the success or quality of your own designs?

E: I evaluate the success and quality of my designs based on factors that are important to me. I consider the user experience and the overall volume and structure of the design. These factors are domain-specific and align with my own standards as an architect.

Q: Do you set the standards for the design projects you work on, or do clients provide requirements and criteria for the objective design?

E: It depends on the project. For individual projects, I set the standards and evaluate the designs myself. I narrow down the alternatives and present them to the clients. However, when working on projects commissioned by clients, they provide requirements and criteria that need to be taken into account during the design process.

Q: What are the main components or factors in the evaluation process of your architectural designs?

E: There are two main components in the evaluation process of my architectural designs. Firstly, I consider the factors that are important to me, such as user experience, volume design, and structural considerations. Secondly, I take into account the requirements and criteria provided by the clients, which can include budget limitations, desired atmosphere, and project site directions.

Q: In the overall design project, which is more important, the factors set by the architect or the requirements set by the clients?

E: Both the factors set by the architect and the requirements set by the clients play a significant role in the design process. While the client's requirements are important as they are the ones paying for the design, it is also essential for the architect to be satisfied with the work they produce. Achieving a balance between the two is crucial for a successful design project.

Q: Have you ever encountered situations where your evaluation of the design differed from that of your clients due to budget constraints or other factors?

E: No, I have not encountered such situations. I always try to adhere to the budget limitations set for

the project. My satisfaction comes from designing the best possible solution within the given budget. I focus on practical and cost-effective design solutions, avoiding projects that require excessive financial resources.

Q: Who participates in the evaluation process to determine whether a design should proceed to production or require modifications?

E: In my experience, I personally evaluate my designs and also consult a few friends who have knowledge and tastes in architecture. I seek opinions from individuals who have different perspectives to avoid bias. Ultimately, the final decision lies with the client. I present the design to them and ask for their feedback and thoughts.

Q: Have you consulted with external organizations or consultants for the evaluation of your architectural designs?

E: Yes, I have occasionally consulted with external organizations or consultants for specific issues or decisions that required expertise beyond my own. While I rely primarily on my own evaluation and the opinions of friends, I am open to seeking input from external sources when necessary.

Q: Are you satisfied with the existing approach to architectural design evaluation?

E: Yes, I am satisfied with the existing approach to architectural design evaluation. I believe that the evaluation should be subjective, considering the artistic nature of architecture. It is challenging to achieve complete objectivity in evaluating designs because they are connected to the architect's personal style and taste. However, I try to imagine how someone else would evaluate my designs to minimize bias.

Q: Have you ever felt that the evaluation of your designs was subjective or biased due to cultural background or personal preferences?

E: The evaluation of designs is inherently subjective because they reflect the personal preferences and cultural backgrounds of the architect. It is challenging to completely eliminate subjectivity in evaluating designs. However, I make an effort to be aware of my own biases and consider different perspectives to minimize their influence on the evaluation process.

Q: What do you think are the limitations of the current approaches to realizing the objective value of architectural design?

E: The current approaches to evaluating architectural design face limitations in achieving objective value. Architecture is a blend of art and engineering, making it difficult to separate the subjective and objective aspects. Personal taste, references, and evolving preferences of the architect can introduce bias into the evaluation process. Additionally, establishing universally applicable objective criteria for architectural design is challenging.

Q: What aspects or criteria do you think the future evaluation approach should focus on?

E: In the future, the evaluation approach should focus on sustainability and circularity. These aspects are increasingly important in the field of architecture, although they may not be widely prioritized in some regions. Considering the long-term impact of designs on the environment and resources should be integral to the evaluation process.

Q: Do you want the intellectual property of your architectural designs to be protected through public licensing?

E: The issue of intellectual property protection in architecture is complex. While it can be disheartening to see others use or modify your designs without permission, it can also be seen as a sign of recognition and interest. For educational purposes, I am comfortable with others using my designs, as it can contribute to the growth of knowledge and learning. However, for commercial purposes, I believe it is important to respect intellectual property rights and obtain proper permissions or licenses.

Appendix F

Logs of interview F

Interviewee : Architect F

Interviewer : Zhijiang Chen

Date : April 24, 2023

Interviewee experience : 4 years of experience of an independent architect, worked for multiple medium-sized project

Q: As an architect, how do you evaluate the success or quality of your designs?

F: As an architect, the evaluation of the success or quality of my designs involves several aspects. Firstly, I consider my personal satisfaction with the design. If I am happy with what I have created, it usually indicates a level of quality. Secondly, the acceptance of my clients plays a crucial role. If the client approves and is satisfied with the design, it can be seen as successful. Lastly, the feasibility and realization of the design are important. Evaluating whether the design can be effectively implemented within given constraints, such as budget and resources, is essential in determining its success.

Q: Do you think the acceptance from your colleagues means/stands for the success of your design?

F: The acceptance from colleagues does not necessarily indicate the success of my design. In architectural offices, especially in collaborative environments, designs are often the result of teamwork. Compliments or feedback from colleagues are not the primary determinants of success. Instead, the focus is on the satisfaction of clients and the alignment of the design with project goals and requirements.

Q: What components/aspects do you care about when it comes to evaluating your architectural designs?

F: When evaluating my architectural designs, I consider various components and aspects. These include personal satisfaction with the design, client acceptance, feasibility, functionality, aesthetics, adherence to project goals and requirements, and the overall impact of the design on the intended users or occupants.

Q: What is the process of the existing evaluation approach of architectural designs?

F: The evaluation approach of architectural designs can vary depending on the context and project. However, in general, the process involves presenting the design to relevant stakeholders, such as clients, colleagues, and other professionals involved in the project. Feedback and critiques are gathered, and discussions may take place to refine and improve the design. The evaluation process can occur at different stages, from initial concept development to final design approval.

Q: Who are the participants of the evaluation process of your architectural designs?

F: The participants in the evaluation process of architectural designs typically include clients, colleagues within the architectural firm, project managers, engineers, and other professionals involved in the project. The specific participants may vary depending on the project and the organization's structure.

Q: Are there any colleagues from other departments/participants from external organizations involved in the evaluation process?

F: In some cases, colleagues from other departments within the organization may be involved in the evaluation process, particularly if the project requires multidisciplinary collaboration. Additionally, external organizations or consultants may be engaged to provide specialized expertise or to meet specific project requirements.

Q: Are you comfortable with people from external organizations evaluating your designs?

F: As an architect, I am generally comfortable with external organizations or consultants evaluating my designs. Their expertise and perspectives can provide valuable insights and contribute to improving the overall quality of the design. Collaboration and feedback from external sources can help ensure that the design meets industry standards and best practices.

Q: Are you satisfied with the existing approach of architectural design evaluation?

F: My satisfaction with the existing approach of architectural design evaluation can vary depending on the specific circumstances and project. While the current approach allows for feedback and collaboration, there may be limitations or biases that can impact the evaluation process. Overall, continuous improvement and adaptation of the evaluation approach are necessary to address any shortcomings and ensure a more comprehensive and objective assessment.

Q: Have you ever encountered situations where you felt that the evaluation of your architectural designs was subjective or biased?

F: Yes, there have been instances where I felt that the evaluation of my architectural designs was subjective or biased. The subjectivity can stem from differences in personal tastes, cultural perspectives, or conflicting project goals and requirements. Bias may arise from preconceived notions or preferences held by clients, colleagues, or evaluators. It is important to engage in open dialogue and consider diverse viewpoints to mitigate subjectivity and biases in the evaluation process.

Q: If so, where do you think those biases or subjectivities come from?

F: Biases or subjectivities in the evaluation of architectural designs can arise from various sources. They may stem from personal preferences, cultural influences, limited understanding of the design intent, or conflicts of interest. Biases can also be influenced by preconceived notions about architectural styles, trends, or perceived market preferences. Additionally, constraints such as budget limitations or time pressures may impact the evaluation process, leading to subjective judgments.

Q: What do you think are the limitations of the current approaches to realize the objective value of architectural design?

F: The current approaches to evaluating the objective value of architectural design have certain limitations. One limitation is the challenge of quantifying subjective aspects such as aesthetics and user experience. Additionally, the evaluation process may not always consider the long-term performance and sustainability of the design. The emphasis on meeting project requirements and constraints within a specific context can sometimes overshadow broader considerations of architectural innovation and societal impact.

Q: Are the limitations or problems in personal or system level?

F: The limitations of the current approaches to evaluating architectural design can occur at both the personal and system levels. Personal biases and subjectivities can impact individual evaluations, while systemic factors, such as project constraints, industry norms, and cultural influences, can also introduce limitations. Overcoming these limitations requires a combination of individual awareness, critical thinking, open dialogue, and continuous improvement of evaluation methodologies.

Q: What evaluation approach are you expecting in the future when it comes to evaluating your designs?

F: In the future, I hope for an evaluation approach that incorporates a more comprehensive and objective assessment of architectural designs. This approach should consider not only the aesthetic and functional aspects but also the long-term sustainability, user experience, and societal impact of the design. It should embrace technological advancements that enable more accurate visualization and simulation of designs, facilitating better decision-making and evaluation.

Q: What aspects should the future evaluation approach focus on?

F: The future evaluation approach should focus on various aspects, including: - Aesthetics and design innovation
- Functionality and usability
- Environmental sustainability
- Energy efficiency and performance
- User experience and well-being
- Cultural and social impact
- Integration of new technologies and materials
- Long-term adaptability and flexibility

Q: What components/criteria should the future evaluation approach include?

F: The future evaluation approach should include criteria that encompass the aforementioned aspects. This could involve a combination of qualitative and quantitative measures, incorporating factors such as visual appeal, spatial organization, energy performance, life cycle analysis, occupant satisfaction, and post-occupancy evaluation. It should also encourage interdisciplinary collaboration to address the complexities of evaluating architectural designs comprehensively.

Q: Do you want the IP of your architectural design to get protected through public licensing?

F: The decision to protect the intellectual property (IP) of architectural designs through public licensing depends on the specific circumstances and goals of the architect or firm. Some architects may choose to protect their designs to retain control and ensure fair use and compensation. Others may prefer an open-source approach, allowing for wider dissemination and adaptation of their ideas. Ultimately, it is a personal and strategic choice that architects make based on their individual aspirations and business models.

Appendix G

Transcripts of interviews

Confidential Content

For the full version of the Appendix, please contact the author(z.chen3@student.tue.nl)

Appendix H

Membership smart contract code

```
// SPDX-License-Identifier: MIT
pragma solidity ^0.8.19;

import "@openzeppelin/contracts/token/ERC721/extensions/ERC721URIStorage.sol";
import "@openzeppelin/contracts/utils/Address.sol";
import "@openzeppelin/contracts/utils/Counters.sol";
import "@openzeppelin/contracts/access/Ownable.sol";

// Author: @Z.Chen
contract ARCHT is ERC721URIStorage, Ownable {
    using Address for address payable;
    using Counters for Counters.Counter;

    struct Application {
        string name;
        address walletAddress;
        string portfolioUrl;
        address[] judges;
        uint confirmationCount;
        mapping(address => bool) confirmations;
    }

    struct Evaluation {
        address requestor;
        address[] evaluators;
        mapping(address => bool) confirmations;
        uint confirmationCount;
    }

    struct RemovalRequest {
        address target;
        uint confirmationCount;
        mapping(address => bool) confirmations;
        address[] rjudges;
    }

    mapping(address => string) public _membersInfo;
    mapping(address => uint) public memberToTokenId;
    mapping(address => uint) public ratings;
    mapping(address => Application) public applications;
    mapping(uint => RemovalRequest) public removalRequests;
    mapping(uint => Evaluation) public evaluations;

    Counters.Counter public _totalSupply;
    uint public evaluationId = 0;
    uint public removalRequestId = 0;
    address payable[] public _members;
    uint public tokenId = 0;

    //Constructor
    constructor(
        address payable member1,
```

```
        address payable member2,
        address payable member3
    ) ERC721("ARCHT", "ARCH") {
        require(
            member1 != address(0) &&
                member2 != address(0) &&
                member3 != address(0),
            "Invalid addresses"
        );

        // Add members and mint NFTs
        _members.push(member1);
        tokenId++;
        _mint(member1, tokenId);
        memberToTokenId[member1] = tokenId;

        _members.push(member2);
        tokenId++;
        _mint(member2, tokenId);
        memberToTokenId[member2] = tokenId;

        _members.push(member3);
        tokenId++;
        _mint(member3, tokenId);
        memberToTokenId[member3] = tokenId;
    }

    function genRandomNum() private view returns (uint) {
        // Pseudorandom number generation
        return
            uint(
                keccak256(abi.encodePacked(block.prevrandao, block.timestamp))
            );
    }

    function applyToJoin(string memory name, address walletAddress, string memory
        portfolioUrl
    ) public payable {
        require(_members.length >= 3, "No enough addresses");
        require(
            address(this).balance >= msg.value,
            "No enough Ether in contract"
        );

        Application storage application = applications[msg.sender];
        application.name = name;
        application.walletAddress = walletAddress;
        application.portfolioUrl = portfolioUrl;

        address payable[] memory tempAddresses = _members;
        for (uint i = 0; i < 3; i++) {
            uint index = genRandomNum() % tempAddresses.length;

            // Assign the member to confirm the application
            applications[msg.sender].confirmations[
                tempAddresses[index]
            ] = false;

            // Add the address to the evaluators array
            application.judges.push(tempAddresses[index]);

            // Remove the member from the temporary array
            tempAddresses[index] = tempAddresses[tempAddresses.length - 1];
            assembly {
                mstore(tempAddresses, sub(mload(tempAddresses), 1))
            }
        }
    }

    function confirmApplication(address applicant) public {
        require(
            applications[applicant].confirmations[msg.sender] == false,
            "Already confirmed"
```

```
        );

        // Confirm the application
        applications[applicant].confirmations[msg.sender] = true;
        applications[applicant].confirmationCount++;

        // Check if the confirmation count is 3 or more
        if (applications[applicant].confirmationCount >= 3) {
            // Add the applicant as a member of the DAO
            _members.push(payable(applicant));
            tokenId++;
            _mint(applicant, tokenId);
            _totalSupply.increment();
            memberToTokenId[applicant] = tokenId;

            // Remove the application from the mapping
            delete applications[applicant];
        }
    }

    function rejectApplication(address applicant) public {
        require(
            applications[applicant].confirmations[msg.sender] == false,
            "Already confirmed/rejected"
        );

        // Reject the application and remove it from the applications mapping
        delete applications[applicant];
    }

    function getApplicationEvaluators(
        address applicant
    ) public view returns (address[] memory) {
        return applications[applicant].judges;
    }

    // Helper function to append to an address array
    function appendAddress(
        address[] memory arr,
        address addr
    ) private pure returns (address[] memory) {
        address[] memory newArray = new address[](arr.length + 1);
        for (uint i = 0; i < arr.length; i++) {
            newArray[i] = arr[i];
        }
        newArray[arr.length] = addr;
        return newArray;
    }

    function requestToRemove(address target) public {
        require(_members.length >= 3, "No enough addresses");

        // Increase removalRequestId
        removalRequestId++;

        address payable[] memory tempAddresses = _members;
        for (uint i = 0; i < 3; i++) {
            uint index = genRandomNum() % tempAddresses.length;

            // Assign the member to confirm the removal request
            removalRequests[removalRequestId].confirmations[
                tempAddresses[index]
            ] = false;

            removalRequests[removalRequestId].rjudges.push(
                tempAddresses[index]
            );

            // Remove the member from the temporary array
            tempAddresses[index] = tempAddresses[tempAddresses.length - 1];
            assembly {
                mstore(tempAddresses, sub(mload(tempAddresses), 1))
            }
```

```
        }

        removalRequests[removalRequestId].target = target;
    }

    function getRemovalEvaluators(
        uint requestID
    ) public view returns (address[] memory) {
        return removalRequests[requestID].rjudges;
    }

    function confirmRemoval(uint requestId) public {
        require(requestId <= removalRequestId, "Invalid request id");
        RemovalRequest storage request = removalRequests[requestId];
        require(
            request.confirmations[msg.sender] == false,
            "Already confirmed"
        );

        // Confirm the removal
        request.confirmations[msg.sender] = true;
        request.confirmationCount++;

        if (request.confirmationCount >= 3) {
            // If 3 or more members confirmed the removal, remove the member
            for (uint i = 0; i < _members.length; i++) {
                if (_members[i] == request.target) {
                    _members[i] = _members[_members.length - 1];
                    _members.pop();
                    break;
                }
            }

            // Burn the NFT associated with the removed member
            _burn(memberToTokenId[request.target]);
            _totalSupply.decrement();
            delete memberToTokenId[request.target];
        }
    }

    function applyForEvaluation(address[] memory evaluators) public payable {
        require(evaluators.length <= 3, "Too many evaluators");

        // Increase evaluationId
        evaluationId++;

        // Store evaluation request
        Evaluation storage evaluation = evaluations[evaluationId];
        evaluation.requestor = msg.sender;
        evaluation.evaluators = evaluators;
    }

    function confirmEvaluation(uint _evaluationId) public {
        require(_evaluationId <= evaluationId, "Invalid evaluation id");
        Evaluation storage evaluation = evaluations[_evaluationId];
        bool isEvaluator = false;

        for (uint i = 0; i < evaluation.evaluators.length; i++) {
            if (evaluation.evaluators[i] == msg.sender) {
                isEvaluator = true;
                break;
            }
        }

        require(isEvaluator, "Not an evaluator");
        require(
            evaluation.confirmations[msg.sender] == false,
            "Already confirmed"
        );

        // Confirm the evaluation
        evaluation.confirmations[msg.sender] = true;
        evaluation.confirmationCount++;
```

```
        // Increase rating for evaluator
        ratings[msg.sender]++;
    }

    function renounceOwnership() public override onlyOwner {
        // Make sure there are enough members to continue running the DAO
        require(
            _members.length >= 3,
            "Must have at least 3 members to renounce ownership"
        );

        super.renounceOwnership();
    }

    function DAOmemberList() public view returns (address payable[] memory) {
        return _members;
    }
}
```

Appendix I

Design evaluation tables

System	Criteria	Sub-criteria	Score (0-5)	Feedback
Sustainability	Burden on the natural environment	Pollution and waste		
		Energy		
		Water use		
		Materials		
		Sustainable land use		
	Quality of the built environment	wellbeing		
		functionality		
	Economy efficiency	technical characteristics		
		cost		
		property value		
Total score				

Figure 48: Sustainability evaluation form

System	Criteria	Score (0-5)	Feedback
Circularity	Carbon footprint		
	Reused content		
	Disassembly Potential & Longevity		
	Design Flexibility & Functional Adaptation		
Total score			

Figure 49: Circularity evaluation form A

System	Criteria	Score (0-5)	Feedback
Circularity	Design for prevention		
	Design with secondary raw materials		
	Design with renewable materials		
	Design for life cycle impact reduction		
	Design for future proof		
	Design with recycled objects		
Total Score			

Figure 50: Circularity evaluation form B

System	Criteria	Sub-criteria	Score (0-5)	Feedback
Multi-level	Technology	Integration of smart technology		
		Energy efficiency		
		Safety features		
	Human factor	Accessibility		
		Usability		
		Inclusivity		
	Aesthesis	Uniqueness		
		Creativity		
		Harmony		
	Culture	Local context		
		Historical relevance		
		Community identity		
Total score				

Figure 51: Multi-level evaluation form