Industry views on optimization in architectural and engineering practice: A CMM study

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ABSTRACT: In architecture and engineering, design professionals may use the term “optimization” to describe a range of design approaches. These working definitions of optimization may not align with one another, or with the formal definition of mathematical optimization in engineering education. This paper presents a thematic analysis of 13 interviews with design professionals who use optimization in their work. Using the communication theory of coordinated management of meaning (CMM) to understand how the interviewer and interviewee were negotiating possible definitions, four themes are identified: optimization as performance improvement, as achieving varied goals, as a systematic process, and as a formal problem structure with variables and objectives, which is most aligned with the mathematical definition. Interviewees used these varied definitions dynamically in conversation, which informs researchers and educators about their potential use in practice.

1 INTRODUCTION AND BACKGROUND

Terminology surrounding “optimization” in the Architecture, Engineering, and Construction (AEC) field has evolved as design optimization approaches have become more accessible. Meanings can vary between subdisciplines or based on where people first encountered certain terms. Zhang and El-Diraby (2012) show how the emergence of new terms in AEC can lead to variations in understanding between academic and industry contexts, resulting in inconsistency. de Oliveira et al. (2024) further highlights a gap in consistency and clarity of terminology in AEC. Academia emphasizes theoretical foundations and precise definitions, introducing terminology grounded in rigorous research to ensure conceptual clarity. In contrast, industry focuses on practical applications, often adopting terminology that addresses immediate challenges and reflects current trends. This practical orientation can lead to informal or context-specific interpretations that differ from academic definitions. However, a unified understanding of terminology across AEC disciplines enhances communication, improves decision-making, and strengthens collaboration (Olsen and Namara, 2021). Consistent terminology also aids in standardizing benchmarks, reducing errors, and aligning academic innovations with industry needs.

Additionally, there is a need to explore how architects and engineers define and apply optimization in their professional discourse, particularly when collaborating or when their roles blur (Bunt, 2023). From an engineering perspective, optimization is a precise mathematical concept in which designers find “the *best* possible solution by changing variables that can be controlled, often subject to constraints” (Martins and Ning, 2021). However, architectural practitioners have conducted optimization in less formal ways (Wortmann and Nannicini, 2017). For example, optimization can be understood as a dynamic balance of multiple design goals (Brown et al., 2020) or a tool for modeling complex phenomena that guides a design towards a best possible outcome (Canestrino, 2021). In building design, optimization can also be viewed as a generative, goal-driven process that leverages Genetic Algorithms (GAs) or similar heuristic approaches to evaluate building designs for optimal performance (Caldas and Norford, 2002).

The tensions in optimization terminology are further exacerbated by disciplinary perspectives. The gap between architecture and engineering is characterized by differing priorities among industry practitioners and subsequent variations in roles and expected contributions (Holzer et al., 2007), which are all shaped by education. Architecture education emphasizes creative, conceptual design thinking, focusing on aesthetics and user experience, while engineering education prioritizes technical problem-solving, functionality, and precision (Cross, 2023). Architecture encourages holistic exploration, whereas engineering focuses on analytical rigor. Despite overlapping in multidisciplinary contexts, each field maintains distinct approaches to design and innovation methodologies, which can obscure shared terminology.

Terminology is also linked to particular design optimization strategies, which are not fully understood (Bunt et al., 2023a). In Bunt et al. (2023b), architecture students are shown to use optimization later, relying on qualitative assessments first, while engineering students apply it earlier and more frequently, focusing on quantitative data. These differing strategies may reflect creative versus technical approaches, suggesting that design education should encourage cross-disciplinary collaboration to balance data-driven analysis with design intuition. Yet as students enter industry with potentially different working definitions of optimization, their terminology surrounding optimization may need to evolve in negotiation with their design collaborators.

Responses to new terminology can vary across AEC, with terms gaining traction in architectural design potentially taking time to be embraced by engineering or construction management (Wood et al., 2013). Many practitioners encounter new terms in the workplace through collaboration and exposure to industry literature, fostering a practical understanding that only sometimes aligns with academic definitions. Yet standardizing terminology in the AEC industry is essential for improving communication and minimizing misunderstandings. For example, a request to optimize a design might lead one part of a team to define performance-based objective functions while another part may start cutting costs. Collaborative initiatives between universities and industry associations can help develop a shared vocabulary that addresses both theoretical and practical terminology. Feedback mechanisms for industry practitioners to share their experiences with new terms can also inform educators and refine curricula, ensuring students are equipped with relevant knowledge for the evolving AEC landscape.

Given the potential benefits of terminological clarity within industry and between industry and academia, this paper first seeks to understand the range of terms currently being used. We address the following research question: what coordinated meanings of “optimization” have architects and architectural engineers developed in their professional discourse? Our research approach is grounded in the communication theory of Coordinated Management of Meaning (CMM), which explains how people create and manage meaning in social interactions. In this study, we interviewed 13 design practitioners with expertise in optimization. The interviews were semi-structured and conducted by a researcher with both academic and practical experience in architecture and structural engineering. A thematic analysis of the interview transcripts reveals several working definitions of optimization that surfaced dynamically during conversation. These themes can provide a deeper understanding of how professionals conducting design optimization at the intersection of architecture and engineering use these varied definitions, enhancing the potential for more effective interdisciplinary work.

2 THEORETICAL FRAMING: COORDINATED MANAGEMENT OF MEANING (CMM)

This study applies CMM to examine how architects and engineers construct and negotiate the meaning of "optimization" in their professional discourse. CMM, developed by W. Barnett Pearce and Vernon E. Cronen, provides a way to understand how individuals create and interpret meaning through interaction (Cushman and Kovacic, 1995). By focusing on coherence, coordination, and the complexity of social realities, CMM can help reveal the processes through which professionals from different fields develop shared understandings. The thematic analysis employed in this work mainly uses the CMM Hierarchy model (Pearce, 2006), which distinguishes levels of meaning, from specific statements to broader cultural narratives. This differentiation is vital for understanding how professionals from distinct disciplines—here, architecture and engineering—connect their specialized knowledge to a definition of "optimization."

3 METHODOLOGY

This study is part of a larger IRB-approved mixed-methods research project characterizing the design behaviors of architects and architectural engineers when constructing and exploring parametric models using optimization tools. This paper presents results of a qualitative phase of research in which the research team gathered insights on design and optimization processes from professionals in both disciplines. An overview of the research design is provided in Figure 1.

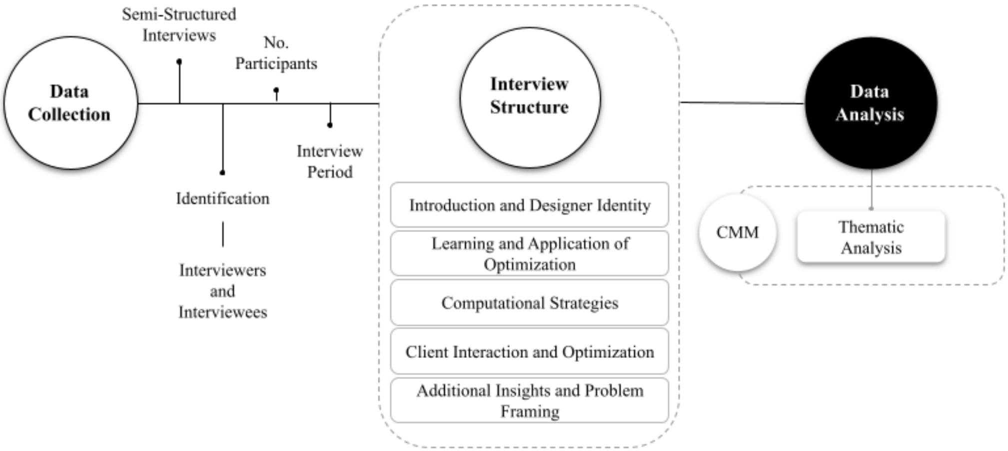

Figure 1. Overview of the research methodology including data collection, interview structure, and analysis.

3.1 *Participants, Recruitment, and Data Collection*

Data were collected through semi-structured interviews (DiCicco-Bloom and Crabtree, 2006) with 13 participants representing industry professionals (6 architects and 7 structural engineers) to explore their personal narratives and professional experiences related to the concept of optimization. The semi-structured format allowed the interviewer to ask follow-up questions and explore participants' answers in more detail (Magaldi and Berler, 2020). Participants were recruited through personal and professional networks and were selected to maximize variation in academic background, years of professional experience, current field of work, and engagement with optimization topics in their practice. All participants were required to be practitioners with at least five prior projects using optimization techniques. Invitations were extended to schedule up to 60-minute interviews via Zoom. Participant backgrounds and relevant contextual information are provided in Table 1.

Table 1. Summary of participant identities, experience with optimization tools, and additional context.

Identity	n*	Years	Work*	GH*	PD*	POT*	Lrn Opt *	n	Location	n
Eng	7	1 to 5	3	2	2	4	Work	4	Denver	1
Arch	6	6 to 10	3	9	8	6	School	7	DC	2
		11 to 15	6	0	0	1	Self-learning	2	NYC	9
		MD*	1	2	3	2	MD	1	KC	1

* n = Number Participants, Work = Work Experience, GH = Grasshopper, PD = Parametric Design, POT= Practice of Optimization, Lrn Opt = How they learned optimization, MD = Missing Data.

The interviews were conducted by an architectural engineering (AE) PhD student with an interdisciplinary background including advanced degrees and professional experience in both architecture and structural engineering. This helped mitigate potential disciplinary disparities. All interviews were audio recorded and transcribed verbatim by a secure online transcription service to ensure the accuracy of the data. Interviewees who completed the interview and participated in a corresponding design study (Bunt et al., 2023b) were offered a $100 gift card.

3.2 *Interview Structure*

The interview process was conducted in several stages to gather specific insights into the interviewee's design practices, optimization strategies, and computational methods.

Introduction and Designer Identity: The interview began with an introduction to the study design task and questions about their approach, providing insight into their design philosophy. The interviewee was then asked to describe themselves as a designer, aiming to profile their design values and identity.

Learning and Application of Optimization: To understand their background in optimization, the interviewee was asked where and how they learned about it. This helped clarify their learning context and its relevance to their practice. They were also questioned about their regular use of optimization, allowing the framing of the design task to be adjusted based on their responses.

Computational Strategies: The interview explored the interviewee's computational strategies by asking how often they use parametric design, aiming to differentiate it from optimization. They were also questioned about their use of design space exploration and related methods.

Client Interaction and Optimization: To contextualize their use of optimization, the interviewee was asked if their clients are aware of and respond to optimization strategies. This helped to understand the client's influence on design goals. The interview also sought to identify gaps in the optimization process by asking what it is missing and how current tools could be improved.

Additional Insights and Problem Framing: The interview concluded by seeking additional insights, asking what other questions should be considered. The interviewee was asked how they frame the problem before starting the design, comparing theoretical and practical approaches.

Throughout the interviews, the interviewer, who carries her own degrees and professional experience in both architecture and architectural engineering, structured the conversations to guide participants in sharing their experiences with optimization throughout their careers.

3.3 *Data Analysis*

Qualitative data analysis, especially deeper interpretive qualitative analysis, often progresses through several rounds of analysis through theory, inductive, and deductive analysis methods. In early passes of the qualitative data, we noticed that the dialogue of "optimization" progressed as a negotiation between interviewer and interviewee. While the interviewer did not provide a definition of optimization to the interview participants, as the interviewer asked follow-up and clarifying questions armed with her own disciplinary expertise, shared meaning-making between interviewer and interviewee became evident, often mimicking interdisciplinary communication. At this point, we began exploring communicative frameworks to capture both the narrative aspects of the data, the disciplinary meaning-making definitional aspects related to "optimization", but also the communal experience for the interviewer and interviewee throughout the interview. Therefore, CMM became our operational framework to frame the content of the participants' responses and the surrounding context provided by the interviewer through dialogue.

3.3.1 Qualitative Coding Methods

We employed a multi-round inductive coding process following guidance from Saldaña (2013). The first pass of data analysis comprised analytic memos that document and reflect on the decisions made during analysis. These memos were crucial in tracking code choices, identifying emerging patterns, and guiding the development of our inquiry while allowing for openness to new insights. This reflective practice ensured that our analysis remained flexible, allowing theory, literature, and unexpected discoveries to guide the research as we identified key patterns.

In the first coding stage, we focused on capturing a nuanced understanding of the data by identifying broader patterns and themes within participants' narratives. Through open coding and categorization, we developed themes that reflected the essence of how architects and engineers describe and engage with the concept of optimization. This initial coding cycle prioritized a holistic view, connecting participants' personal experiences with their professional discourse. In the second coding cycle, we applied theoretical coding to synthesize the themes into a central theory. This axial coding stage aimed to integrate all categories into a coherent framework, linking the core theme of "optimization" to the other codes and categories.

By combining thematic analysis with theoretical coding, the research not only categorizes recurring themes but also delves into how individual experiences of optimization intersect with broader societal influences and professional norms. This approach deepens the understanding of how personal stories, shaped by cultural and professional contexts, influence the construction of meaning in interdisciplinary collaboration. Together with CMM, this method paints a picture of the dynamic ways professionals negotiate concepts like optimization in their work.

3.3.2 Positionality and Roles of the Research Team

In qualitative and interpretive research, the quality of the research is governed and influenced by who the researchers are (Yadav, 2022), since researchers are the data collection instruments themselves. Certain interviewers, because of shared roles, ability to form rapport, or other attributes, may be able to elicit different experiences and interview responses than other interviewers. We also note that our positionalities as researchers influence the research choices and priorities we hold; the theories we choose; and the methods employed to analyze data. Interpretive methods depend on the researchers' application of theory, such that a different constellation of researchers may elicit different but complimentary patterns in the data. Similarly, the curated sample of practitioners reflects a subset of experiences. The goal of qualitative data is to understand rich phenomena of interest rather than generalizable or statistically significant results.

Regarding positionality and research team roles, all interviews were conducted by a single PhD student with degrees in architecture, civil engineering, and AE, as well as professional experience in industry prior to the interviews. This positionality provided a unique opportunity to ask targeted and interesting follow-up questions during the interviews. A second PhD student in architecture coded the transcribed interviews, and all research decisions were reviewed by the interviewer and two professors supervising the project. One of the professors is an Architectural Engineering Assistant Professor with substantial expertise in structural and multi-objective optimization, and the other is an Associate Professor of Mechanical Engineering whose research expertise is in engineering education research, specializing in qualitative methodologies.

3.3.3 Limitations

The study sample size includes participants with diverse backgrounds in architecture and engineering and varying years of professional experience. We note that some had multidisciplinary backgrounds and work environments; more participants would be needed to draw specific conclusions about architects versus engineers. We also acknowledge that there are industry professionals across the world whose perspectives cannot be captured. It was difficult to gain access and willingness to participate from industry professionals, who are busy and often working on high-pressure projects, which perhaps impacted participation. The geographic concentration in a few U.S. cities may also overlook regional variations in practices and cultural influences.

4 RESULTS AND DISCUSSION

Using CCM enabled a recognition of the complexity of communication, revealing that definitions of "optimization" vary depending on the context of each interaction. This led to an exploration of how factors such as organizational culture, individual experiences, and situational contexts combine to shape participants' understanding of optimization. By examining these influences, deeper insights were gained into how multiple interpretations coexist and inform one another in the process of communication and meaning-making. The thematic analysis identified four themes that categorize the participants' dynamic definitions of "optimization," as illustrated in Figure 2.

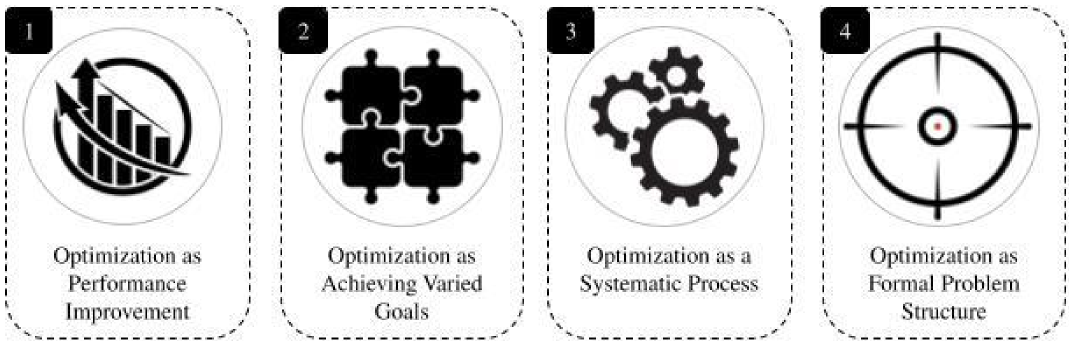

Figure 2. Four themes regarding use of optimization among interviewees.

As described in the last section, a coding process was used while identifying sub-themes. This process categorized the interviewees' responses and grouped them to illustrate how the themes emerged. Table 2 presents the sub-themes, their definitions, and examples of the coding process.

Table 2. Example sub-themes, definitions, and coding.

Sub-theme	Definition	Example Coding
	1. Optimization as Performance Improvement	
Improvement	-Optimization as an improvement in results	Make design better
Time	-Optimization as a means of saving time	Time efficiency
Cost	-Optimization as a strategy for cost reduction	Cost reduction
Management	-Optimization as a way to enhance management	Budget constraints
	2. Optimization as Achieving Varied Goals	
Construction	-Optimization as achieving constructability of the design	Design buildability
Materials	-Optimization as achieving constructability of the design, informed by materials and fabrication methods	Material reuse
Qualitative Goals	-Optimization as balancing performance with aesthetics and client needs	Balancing aesthetics
	3. Optimization as a Systematic Process	
Defined Method	-Optimization as a defined process, but one that does not necessarily involve automated selection of the best possible design	Monte Carlo Analysis
Design Space	-Optimization as design space exploration	Prioritize objectives
Algorithmic Design	-Optimization as generative, algorithmic, or parametric design but without the defined variables and objectives of the formal approach	Algorithmic design
Satisficing	-Optimization as finding "best" answers within an acceptable range	Best answer
Range	-Optimization as generating a spectrum of possible solutions that lead to favorable outcomes	More than one optimized option
	4. Optimization as Formal Problem Structure	
Elements	-Optimization discussed with specific variables and objectives	Minimize objective
Algorithms	-Optimization discussed with specific algorithms	Evolut. algorithms
Tools	-Optimization discussed with specific tools	Galapagos, Goat

4.1 *Descriptions and Discussion of Themes*

Optimization as Performance Improvement – Many interviewees define optimization as finding a better design option from a range of alternatives to enhance a performance metric—rather than identifying the single best solution—aligning with a broad, flexible theme. Some used optimization to refer to improving *design processes* or *digital workflows* rather than the design itself. For instance, individuals in senior positions frequently referred to optimization in terms of practical benefits like saving time, design automation, cost reduction, and improved project management: "We can better improve the day-to-day tasks that we do, whether that's automation, optimization, or just other workflows that save time." When encouraged to differentiate optimization from a more general approach to exploring design spaces, those with more experience in optimization or who studied it formally often provided more precise definitions that can fit in with other themes.

Optimization as Achieving Varied Goals – Some practitioners described optimization as improving the aesthetics or buildability of a design while working within structural, material, and other constraints. The main goal is often to ensure that the design can be built and is practical. In this context, optimization focuses on making the design more accessible to construct by considering factors like available materials, fabrication methods, and real-world limitations. Instead of always aiming for quantifiable optimization, practitioners often define success as finding the best workable solution within these constraints. One interviewee gave this example: "We had a complex rock structure with irregular geometry, and optimization helped us simplify the design, figure out structural support, and check our solutions efficiently. That's where optimization shows its value." Practitioners noted that their approach often shifts based on client needs. They prioritize meeting the client's expectations rather than always striving for the most technically optimized solution. This means that optimization sometimes involves focusing more on the client's vision than on achieving a perfect design, striking a balance between performance and practicality.

Optimization as a Systematic Process – This theme describes optimization as a structured approach to discovering good design solutions and improving design outcomes. Sometimes, optimization is used to refer to generating and manually filtering options using data visualization, which could instead be called design space exploration. Some practitioners employed precise technical terminology and emphasized thoroughly exploring the entire design space. This process has well-defined objectives serving as the guiding force while finding an effective result or managing trade-offs in multi-objective problems. There is not always a singular "best" solution. Instead, designers seek to uncover a range of optimized outcomes within specific parameters, embracing the complexity and diversity of potential solutions while balancing various factors. One interviewee captured this dynamic by explaining: "I found it incredibly useful when faced with multiple design decisions. Instead of relying on the designer to narrow down a few preferred options, I integrated all of the choices into a broad design space. After analyzing the results, I recommended staying within specific ranges." Although this theme does not always involve automated algorithms or minimizing objective functions, it still reflects a disciplined approach.

Optimization as Formal Problem Structure – This terminological usage of optimization in design is closest to mathematical optimization, as it involves systematically formulating problems by clearly defining objectives, design variables, and constraints. In professional contexts, practitioners often articulate their understanding of optimization through specific terms and tools, such as "evolutionary algorithms" and "Galapagos". During interviews, participants provided concrete examples from their experiences. For instance, one interviewee described: "The geometry was generated with some sort of NURBs surface in Rhino, and then it was meshed in Grasshopper, and then it was optimized and analyzed with Karamba and put through a Galapagos loop." This workflow exemplifies a current approach to optimization in practice, integrating advanced computational tools to refine design outcomes.

CMM helps to understand how these themes, and corresponding definitions, might have arisen through communication in AEC. Interview responses about project work often involved "stories told", which are developed from the meaning given by the person telling the story, or by the broader community, to various experiences. In the workplace, participants may have assigned the term "optimization" to diverse range of projects or processes, and this meaning might have been reinforced by collective usage by colleagues with similarly broad definitions. In the topically focused interviews, participants may have extended their coordination of meaning in dialogue with the interviewer, leading to evolving and increasingly precise definitions during the conversation.

4.2 *Summary of Themes and Related Definitions*

In summary, the research uncovered four primary themes, which can potentially correspond to working definitions of optimization in use by practitioners. Our interpretation of these definitions is provided in Table 3. We acknowledge that there is some ambiguity in what constitutes a "used" definition. For example, an interviewee may not specifically say the word "optimization" but may respond to an interview question such as "how do you use optimization in your work?" by describing a story involving performance improvement or enhancing constructability. Given the dynamic interactions between interviewer and interviewee, the researchers had to interpret when a certain usage was implied by the context of the question.

Table 3. Definitions of optimization corresponding to each theme.

Performance improvement	Finding a better design option from a range of alternatives to enhance a performance metric. The performance could involve improving time, cost, or design quality. This definition is used while focusing on whether the outcome (or sometimes workflow) has improved, regardless of process.
Achieving varied goals	The process of enhancing the aesthetic or buildability aspects of a design within structural, material, and other constraints. This definition focuses on limitations that affect the design, and how to achieve optimal results that meet client needs, balancing creativity with practical considerations.
Systematic process	A structured approach to finding a good solution or range of solutions by using a systematic procedure. This could include using optimization to describe a decision matrix, parametric simulation, or design space exploration, which are methodical but do not necessarily use an automated optimization algorithm to minimize an objective function.
Formal problem structure	Formally defining the problem in terms of objectives, variables, and constraints. The goal is to find the optimal solution by minimizing an objective (or fitness) function. Most approaches use a computational optimization tool to automatically search for solutions.

5 CONCLUSIONS

In conclusion, this qualitative thematic analysis highlights varied interpretations of "optimization" within professional contexts. Architects and engineers often define optimization differently depending on the focus of their work. Many professionals view any improvement—such as reducing construction costs or speeding up design and analysis—as a form of optimization. Others emphasize project-specific considerations, such as enhancing constructability, while some frame optimization as finding the best solution to a given problem by clearly defining objectives and variables. A better understanding of how these varied definitions are used in practice can help promote standard terms, enhancing future interdisciplinary collaboration and design optimization.

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