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By

John Chachere & John Haymaker

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If you would like to contact the authors, please write to:

c/o CIFE, Civil and Environmental Engineering Dept.,
Stanford University
The Jerry Yang & Akiko Yamazaki Environment & Energy Building
473 Via Ortega, Room 292, Mail Code: 4020
Stanford, CA 94305-4020

Framework for Measuring Rationale Clarity of AEC Design Decisions

John Marvin Chachere, Ph.D.[1] and John Riker Haymaker, Ph.D., AIA, LEED AP[2]

Abstract

Current Architecture, Engineering, and Construction (AEC) design processes rely on precedent to resolve complex decisions. However, changing stakeholder concerns, design methods, and building products negate much of this precedent knowledge. Project teams need to clearly communicate their decision rationale in order to develop consensus about design decisions. The AEC industry requires a new framework to evaluate decision making. This paper builds on a broad range of theory including Decision-Based Design, Decision Analysis, Decision Theory, linguistics, logic, organization theory, and social welfare. First, this paper describes rationale as a set of assertions regarding distinct components (i.e. managers, stakeholders, designers, gatekeepers, objectives, constraints, options, and analysis) that support design decisions. Second, this paper describes conditions of clarity (i.e. coherent, concrete, connected, consistent, convincing, certain, and correct). These are used to measure the clarity of assertions, components, and the rationale as a whole. Taken together, this Rationale Clarity Framework (RCF) enables an objective evaluation of existing decision support methods. RCF provides a broad yet structured view for assessing process, organization, and product performance and for assessing AEC industry dynamics.

Keywords: design; decisions; rationale; management; project management; clarity; rationale clarity framework; decision making

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[1] Consulting Assistant Professor, Center for Integrated Facility Engineering, Department of Civil and Environmental Engineering, Stanford University, MC:4020 Stanford, CA 94305 chachere@stanford.edu

[2] Assistant Professor, Center for Integrated Facility Engineering, Department of Civil and Environmental Engineering, Stanford University, MC:4020 Stanford, CA 94305 haymaker@stanford.edu

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INTRODUCTION

The theory and practice of Architecture, Engineering, and Construction (AEC) project management urgently require a method to structure rationale information and discern its clarity. This paper proposes a detailed definition of AEC Design Decision Rationale (DDR) and its components, provides a method to measure the clarity of this rationale, and discusses the interdependencies between the DDR components and the conditions of clarity. Together, these definitions form the Rationale Clarity Framework (RCF). Applying the RCF for a specific project consists of reducing project documentation into individual assertions, evaluating their clarity, and reporting the aggregate conditions of clarity in each assertion, component, and the overall rationale.

Supporting every design decision, there are reasons that collectively form a design rationale. Applying theories of decision making and organizations reveals the rationale contains several essential and distinctive parts. These are called components, such as design options (e.g., steel or concrete structures), project objectives (e.g., minimize cost and duration), and constraints (e.g., fire safety codes). Each rationale component, in turn, consists of several individual claims, called assertions, such as “The building could use a steel moment frame for its structure,” “Each day’s delay is worth $1M to the owner,” and “The local fire code requires a window in each bedroom.” Since a rationale consists of components, and a component consists of assertions, this paper defines the clarity of an overall rationale as equal to the clarity of its weakest assertion.

A broad range of influential new design methods and technologies (e.g., LEED and BIM) act primarily to clarify data that form the rationale for design decisions. At the level of projects, lack of clarity in rationale often serves participant self-interest at the expense of team and building performance, and clarifying decision rationale typically faces technical and organizational challenges (Chachere and Haymaker, 2008a). At the level of industry, rationale clarity is the foundation of well-functioning organization that takes advantage of modern trends such as information technology and globalization (Chachere and Haymaker, 2008b). A standard definition of clarity facilitates scientific understanding and communication. It also creates an opportunity to benefit from project and industry trends.

After reviewing traditional practice and relevant theory, this paper provides a theoretical framework for measuring rationale clarity. The end of the paper discusses theoretical propositions about the effects of clarifying rationale on AEC organizations and the industry, and provides an example presentation method to display the rationale clarity status of one project decision.

POINTS OF DEPARTURE

This section identifies a gap in current AEC (Architecture, Engineering, and Construction) design practice and theory: Standard, theory-based definitions of design decision rationale and rationale clarity are missing. Such formal definitions can help project managers assess and improve decision making. Without them, there are no guarantees of success or long-term improvement (March and Olsen 1985). Project teams currently develop a rationale for each individual decision, often incorporating essential information into a set of inconsistently, or weakly, standardized documents that do not broadly communicate the reasons for a design decision with clarity. Most relevant theories to guide practitioners are fragmented, so that a high-level view of design decision rationale is difficult for management and researchers to grasp.

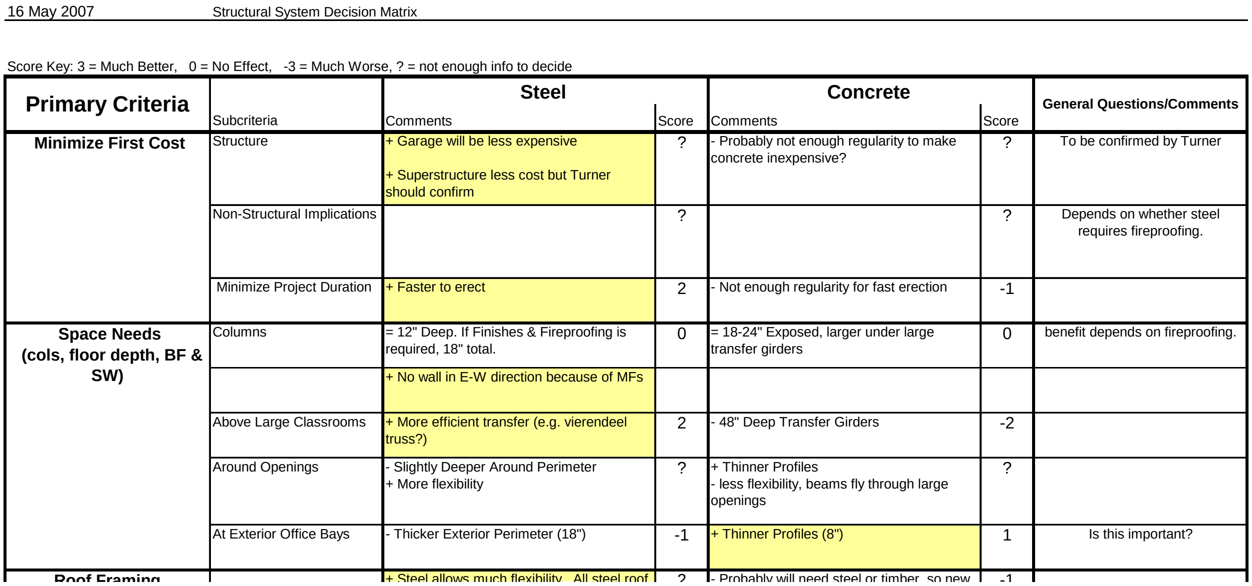
Practical Points of Departure

Every building and infrastructure project includes a conceptual design stage during which a team decides on one of several configurations. Stakeholders, designers, gatekeepers, and managers collaborate to produce complex decisions while trading off competing priorities. Institutional strengths and weaknesses in this collaboration systematically influence building feature decisions and determine the effects of our building and infrastructure on the economy, environment, and society (McDonough and Braungart 2002, Chachere and Haymaker 2008a, 2008b). The AEC industry requires an objective method to assess the clarity of design rationale and building design decisions.

Traditional Practice

A clear rationale requires the development of a broadly available and understandable reason supporting a decision. In our field studies, typical AEC practices failed to deliver basic information that project teams need to identify and build consensus on a design (Haymaker et al. 2008). Figure 1 shows a matrix presented by a design team to an owner to build consensus for the selection of a steel structural system. However, the matrix alone does not provide a clear rationale to support any decision. As shown, the identities of stakeholders and gatekeepers involved in the decision are unstated. Numerous goals are identified without indicating their relative importance. The options are stated vaguely. The certainty attached to individual analyses is not always communicated. Finally, no recommendation or decision is recorded in the matrix. Because of these gaps, this document is open to multiple contradictory interpretations. Clearly, it needs to be extended with additional material, such as narration, meeting minutes, or 3D models, to convey any substantial, objective meaning. Project teams require a more integrated method for documenting and communicating decision rationale to the project team.

Figure 1
Decision Matrix
Source: Haymaker et al. 2008



16 May 2007 Structural System Decision Matrix

Score Key: 3 = Much Better, 0 = No Effect, -3 = Much Worse, ? = not enough info to decide

Primary Criteria		**Steel**		**Concrete**		**General Questions/Comments**
	Subcriteria	Comments	Score	Comments	Score	
Minimize First Cost	Structure	+ Garage will be less expensive + Superstructure less cost but Turner should confirm	?	- Probably not enough regularity to make concrete inexpensive?	?	To be confirmed by Turner
	Non-Structural Implications		?		?	Depends on whether steel requires fireproofing.
	Minimize Project Duration	+ Faster to erect	2	- Not enough regularity for fast erection	-1	
Space Needs (cols, floor depth, BF & SW)	Columns	= 12" Deep. If Finishes & Fireproofing is required, 18" total.	0	= 18-24" Exposed, larger under large transfer girders	0	benefit depends on fireproofing.
		+ No wall in E-W direction because of MFs				
	Above Large Classrooms	+ More efficient transfer (e.g. vierendeel truss?)	2	- 48" Deep Transfer Girders	-2	
	Around Openings	- Slightly Deeper Around Perimeter + More flexibility	?	+ Thinner Profiles - less flexibility, beams fly through large openings	?	
	At Exterior Office Bays	- Thicker Exterior Perimeter (18")	-1	+ Thinner Profiles (8")	1	Is this important?
Roof Framing		+ Steel allows much flexibility. All steel roof	?	- Probably will need steel or timber, so new	-1	

In this example, the designers simplified the rationale information. Two problems stand out. First, they assumed a shared knowledge of precedents. Second, they invoked trust based on the authority of their professional credentials. The next section proposes that continuing this common designer practice may not benefit AEC projects (Chachere and Haymaker 2008a) or the AEC industry (Chachere and Haymaker 2008b).

Modern Developments

In the last twenty years, the AEC industry has entered a period of turbulence in which many types of previously slow-changing information altered rapidly. Globalization and urbanization have introduced a broader community of stakeholders, designers, and gatekeepers. Information technology has heightened awareness of relevant events. Natural disasters (e.g., Hurricane Katrina), terrorist attacks (e.g., 9/11), and popular films (e.g., An Inconvenient Truth) have heightened stakeholder sensitivities to diverse goals, such as durability, security, and sustainability. In turn, these new goals have led to the development of new options including spatial configurations, structural systems, and energy production schemes. Information technology has yielded new ways to represent and analyze the performance of different options.

AEC project organizations have not yet developed consistent shared knowledge and authority relationships around this new information. Currently, there are many standards of communication and coordination addressing various components in the design rationale. Some address different components of the design rationale (e.g., Building Information Modeling (American Institute of Architects 2008), and focus groups) and some standards overlap (e.g., LEED (U.S. Green Building Council 2008) and SPeAR (Arup 2006)). While each of these standards helps to clarify some aspect of design rationale, none addresses the full scope of relevant information with enough clarity to develop and communicate this rationale convincingly.

Theoretical Points of Departure

This section reviews research in design decision making methodologies. Generally, we conclude a model of rationale clarity for the AEC industry has not yet been formulated. However, there is significant related research on the use of Decision Analysis (DA), Decision-Based Design (DBD), Decision Theory (DT), and Decision Rationale

(DR). Research on DA and DBD generally focuses on an ‘optimal’ choice and treats clear communication as a valuable but secondary effect. Previous efforts to formalize and communicate DR demonstrated the ability to “record and playback” rhetorical design thinking, but lacked the structure needed to efficiently capture and reuse knowledge, generate new insights, and communicate and develop consensus (Moran and Carroll 1996). As a result, DR methods have not yet had a significant impact in practice.

“Many of the fundamental questions (regarding DR) have barely been raised” (Moran and Carroll 1996). Questions remain about the fundamental components of rationale. How much of the rationale should be made explicit? Who should construct and consume this rationale? What are the likely impacts of clarifying this rationale? The first step toward answering those questions is to formally define rationale and rationale clarity in an AEC conceptual design context.

This paper supports addressing these fundamental questions by providing a formal definition of rationale clarity for AEC design decisions. We describe existing theory about design decision rationale and how project teams interact to construct and manage this information. We synthesize this theory and our own field observations to create a model of the components of AEC decision rationale and a method to assess its clarity.

Limits on Rationality

Psychological and organizational limits constrain rational administration on design projects. Virtually all design decisions are too complex for individuals and organizations to address with absolute clarity. This situation results from limited knowledge of options, analyses, and preferences, and a limited ability to process this information (Simon 1977). In general, time and cost pressures present strict limits on the clarity AEC design organizations can achieve. Practitioners understand that rationality is limited, and strive to work around it. During this research, a project manager for a $300M hospital stated to us, “My goal is a significantly better method that’s workable, not an ideal method.” The optimal degree of rationale clarity for a project to attempt, and the method for attempting it, depends therefore on the resources available. Simplification, which includes data classification and uncertainty absorption (March and Simon 1958), is a necessary evil; “Simplification may lead to error, but there is no realistic alternative in the face of the limits on human knowledge and reasoning” (Simon 1977).

Increasing project complexity further challenges an AEC team to make rational decisions. Conversely, advancing computer processes and visualizations reshape the boundaries of rationality. Assessing these changes requires measuring and comparing current and ideal practice. Existing research uses the notion of rationality to assess organizational behavior using the general rational framework (March 1994), and to assess the quality of decisions.

Design as Decisions

The rational decision making view provides a theoretically defensible foundation for a formal model of rationale. Design consists of many interdependent decisions (Lewis et al. 2007). These decisions are complex. Each option has associated objectives, constraints, and analyses regarding performance characteristics that may be uncertain. These decisions are also numerous. There are vast numbers of interdependent choices possible, and many of them interact. Since the total complexity of assessing all decisions is unmanageable, project managers divide the problem into manageable portions (Simon 1977). AEC projects can be partitioned so design decisions occur in a sequence of “stages.” The sequence starts with fundamental questions (e.g., building location and orientation) and is followed by progressively detailed decisions (e.g., plumbing and lighting fixtures). Project management arranges the work within a stage to assess design decisions and produce a defensible set of choices. Ideally, the product of that stage provides all the information required to make a decision. For example, if a first stage site selection decision culminates in a particular building orientation, then the next stage (which may decide the structural system) will be based on that orientation.

Decision Theory and Decision Analysis

Project management may assess simple decisions formally and guide complex decisions informally using Decision Theory (DT). Classical economics, game theory, and operations research optimization methods use DT’s simple, formal basis for making good decisions under uncertainty. DT uses widely-accepted axioms to derive a normative rule for rational decision making: the best course of action is the one maximizing expected utility (a personal measure of usefulness) (Ramsey 1931, von Neumann and Morgenstern 1944, Savage 1954, Fishburn 1964, Matheson and Howard 1968).

In particular, Decision Analysis (DA) applies DT in the form of “a structured conversation leading to clarity of action” that may be useful for strategic decisions under uncertainty. DA consists of developing a mathematical, probabilistic model of an individual’s options, analyzing the possibilities, and assessing the decision maker’s preferences regarding the possible outcomes.

DT applies to individual decision makers only, and traditional DA focuses on supporting individuals. However, the DA framework can provide a structure for communication and reasoning in AEC organizations. Decision analysts have placed increasing emphasis on analyzing and adapting to organization and procedure (Keefer et al. 2007). Nevertheless, DA often requires few collaborators and addresses an individual’s choice. This practice is unlike building design in which decisions almost invariably require broad collaboration and benefit greatly from consensus.

Decision-Based Design

Decision-Based Design (DBD) applies Design Science and DA methodologies to solve design problems. Moran and Carroll (1996) ask questions such as: “How deeply can we understand design as a generic activity? How can we represent not only the reasons for solutions to subproblems, but also for the tradeoffs and compromises made to adjudicate between the demands of the different subproblems?”

Thurston (2007a) formulates design as an optimization problem, distinguishing design options, goals, preferences, analyses, and constraints. Research also defined methods to decompose difficult optimization problems into smaller, simpler problems, solve them in a decentralized fashion, and synthesize them into system optimal solutions. Some properties of the hierarchical optimization method match theories of organizational behavior (Burton and Obel 1980). In particular, the paradigm is analogous to organization into design trades that report formally to a central decision maker. Renaud and Gu (2007) provide a mathematical decision-based collaborative optimization (DBCO) method of making simultaneous design and business decisions.

Kumar et al. 2007 provide a hierarchical view with enterprise-level product planning decisions driving engineering-level product design decisions within a mathematical, multi-level optimization. Their method’s decomposition of the problem and the process addresses computational and organizational complexities in the early stages of design. Hermann and Schmidt 2006 describe design organizations as systems for producing decisions. They point out bounds of rationality in product development decisions: "Viewing a product development organization as a decision-making system leads to a systems-level approach to improving product development." Other researchers have argued that the system perspective is necessary for effectively implementing DA (Matheson and Matheson 2007). This paper pursues the view that efficient decision making methods enforce system thinking, and vice versa. "While efforts should be made to extend the envelope of the rigorous decision theory in the design field, another approach is to adapt the principles of design theory to create practically applicable design methods" (Jin and Danesh 2007 p.298).

Design as decision making and design as process execution are complementary views (Donndelinger 2007). In AEC, DBD methods can help clarify many aspects of AEC design rationale in principle (Chachere and Haymaker 2008a, 2008b) and practice (Haymaker and Chachere 2006, Haymaker et al. 2008). The formulation matches the high level structure of many design problems. However the need to incorporate diverse stakeholder objectives provides an additional structure that is central to AEC. AEC design decisions rely on clarity and consensus among a wide range of participants who may be unwilling or unable to understand highly technical design documents. Efficient Decision-Based Design (DBD) requires evidence of decision quality that is easily communicated to project participants.

Design Rationale

There has been much research on formal models of Design Rationale (DR) but little success institutionalizing them in practice. A DR is a document that provides explicit, logical reasons given intended to justify decisions on the design or features of a building (for details, see Moran and Carroll 1996 pp. 8-9). A DR is a product of reflection on the construction of a design (Schön 1983), and its purpose is to "rationalize discussion" (Fischer et al. 1991). Moran and Carroll (1996) ask, "What types of rationale are there?" Next, process-oriented and structure-oriented rationales are discussed. In this paper, we apply structure-oriented rationale to AEC design.

1.1.1.1. Process-Oriented Design Rationale

A process-oriented design rationale emphasizes the design rationale as a "history of the design process" that can nevertheless help find design errors (Conklin and Burgess-Yakemovic 1991). The practice relies on rhetoric. "Its qualitative approach avoids the complexities of multi-attribute utility theory…and the quagmires of arbitrary and hair-splitting quantitative judgments." Researchers began formally modeling design rationale decades ago to deal with "wicked" problems that have many complex interactions but little known structure (Rittel and Weber 1973). The seminal design rationale representation, Issue-Based Information System (IBIS), was built to help designers clarify and communicate design and planning for such problems (Rittel and Weber 1973). IBIS consists of a network of related textual statements: issues, positions regarding issues, and arguments for or against positions. The overall success of semiformal design rationale in industry has been decidedly mixed (Fischer et al. 1991). Research and practice has found IBIS "too simple and homogeneous… to support decision making in the presence of change…(these original methods) tend to ossify and become impossible to revise or extend" (Potts 1996 p. 318). While explicit design rationale "reduces the chances of missing some important consideration" (Fischer et al. 1991), it also relies upon decision makers to realize the existence and relevance of that information. Without structure, "The (design rationale) document can grow into an unwieldy amount of loosely organized textual information… repeated occurrences of an issue will usually be worded and even conceived of differently (and) the (design rationale) document will grow to contain inconsistent information" (Conklin and Burgess-Yakemovic 1991).

1.1.1.2. Structure-Oriented Design Rationale

Research has addressed perceived deficiencies in process-oriented design rationale by leveraging knowledge about the structure of design work. For example, some models explicitly articulate design goals (Lee and Lai 1991, McLean et al. 1991), or incorporate industry-specific design methods (Potts 1996). A structure-oriented design rationale "emphasizes the careful construction of (design rationale) as a map of the design space and focuses on a rigorous and logical representation of the rationale. This approach maximizes the payoff of (design rationale) through its reuse and/or through lowering the cost of system maintenance" (Conklin and Burgess-Yakemovic 1991). McLean et al. 1991 provide an example of structure orientation.

Acceptance of design rationale depends upon its match to process (Conklin and Burgess-Yakemovic 1991). However, theory has does not yet contain a definition of the components of design rationale, or the clarity of that rationale, for the AEC process.

RATIONALE CLARITY FRAMEWORK (RCF)

Moran and Carroll (1996) ask, "How far can we characterize the structure of design abstracted from specific domains?" This section responds by building on previously discussed decision and organization theories to structure a formal definition of clarity in AEC Design Decision Rationale (DDR). Projects generate numerous materials to support design choices, including rhetorical arguments, references to building codes, and models. Each of these materials provides numerous individual claims that are relevant to the design rationale, called assertions. This section defines the RCF's two views. The first view is that each assertion addresses one or more of a set of components (e.g., options, constraints, and objectives) that span the necessary and sufficient information to explain design decisions. This section explains how these components follow from the organization of AEC design and from theories describing the fundamental requirements of decision making. The second view is that each assertion in a rationale satisfies conditions of clarity (e.g., concrete, convincing, and consistent). This section provides a way of describing the project team's achievement of clarity in design rationale by defining and comparing several definitions of clarity from literatures such as linguistics, logic, and organizational theory.

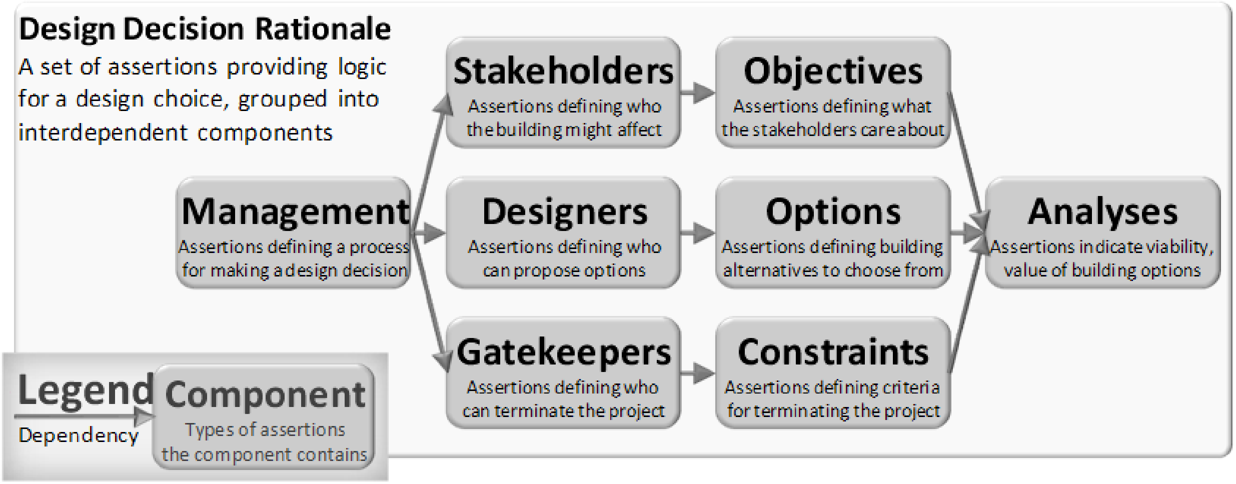
For example, the decision matrix presented in Figure 1 encodes assertions such as, “Choosing the steel structure scores a 2, meaning ‘much better,’ for project duration.” The assertion regards the analysis component of a rationale, meaning that it measures the effect of an option on project objectives. In terms of clarity, the example assertion is coherent but vague. This means that it makes grammatical sense, but it is vulnerable to subjective interpretation. The project team needs to determine whether a faster time to erect the steel structure is worth the cost. This would require greater precision than the term ‘much better’. By contrast, a different assertion such as, “The steel structure will be 4 weeks faster to erect” would provide an analysis that is both coherent and concrete, because it is objectively measurable.

Viewing the DDR documents in terms of components and clarity reveals which portions are clear, and are therefore supportive of a decision. It also reveals which portions are unclear, and are therefore vulnerable to criticism. RCF also dictates how unclear assertions limit overall clarity. Maximizing this framework includes recognizing dependencies in the achievable clarity within components. For example, objectives must be coherent before they can be convincing because incoherent assertions carry no meaning. There are similar dependencies in the achievable clarity between components. For example, stakeholders must be concrete for the objectives to be concrete. This is because objectives express the preferences of stakeholders.

Rationale Components

Howard (1983, 2008) provides a set of criteria for judging decision quality to guide attention toward weaknesses in the application of DA. This section builds upon Howard’s work by defining numerous conditions of clarity in each component that are appropriate in evaluating the documentation of AEC design decisions. Figure 2 shows the components that RCF defines for DDRs.

Figure 2
Components and Dependencies of AEC Design Decision Rationale (DDR)



Moran and Carroll (1996) ask, "Who will create the rationale?" Organization is central to the formation of DDR. Contemporary design integration in the Architecture, Engineering, and Construction (AEC) industry is socially complex. Participants (e.g., planners, architects, engineers, and contractors) design, construct, and operate the buildings and infrastructure that help sustain human life and society. The organization of these projects influences views of their decision making. Descriptively, "Organizations will have structure… insofar as there are boundaries of rationality" (March and Simon 1958 p. 170). Normatively, "An organization using Decision Analysis (DA) agrees to act as if it were a single entity using the logic of a person. Separate groups might have the assignment of creating the frame and the elements of the decision basis" (Howard 2008). The general rational framework (March 1994) views decision making in terms of both organization and decision components, and this view provides a structure that assists describing and comparing both traditional practices and theoretical improvements to practice.

In these projects, knowledge regarding decision rationale is generally distributed among four role types. Note that individuals can take on multiple roles.) The following sections introduce the distinctive features of each role type: Managers know process and organization; Stakeholders know goals and preferences; Gatekeepers know constraints limiting the project; and Designers know options and analysis.

Managers

A DDR should state who supervised the project organization, process, and technology. It should also provide administration of the design reasoning, judged by Howard (1988) as “logical integration and evaluation,” to define how decision data determine the choice that is made.

Managers provide expertise and leadership regarding process (stages and gates) and organization (stakeholders, designers, and gatekeepers). They use formal and informal processes to integrate the decisions of many individuals into a set of collective, rational design decisions. “The problem is one of organizing the entire system of decision-making and information flow” (Hermann and Schmidt 2006 p. 236).

A principal management role is assigning resources (such as time and money) and establishing procedures to guide the broadest possible range of creative ideas through the most rigorously critical evaluation. The manager therefore identifies the designers who can propose and analyze options, the gatekeepers who can prohibit construction of options, and the stakeholders whose objectives the building might affect.

A DDR should state which option the team selected. In a rational decision making method, the combination of valuation (appropriately weighted social benefit) and viability (satisfaction of all constraints) determines the decision. The best choice is the viable option with the highest value to the manager (or other decision makers).

Stakeholders

A DDR should state what groups of people the design might affect. This is fundamental to addressing Moran and Carroll’s (1996) question, “How can rationale methods and tools be used to expand the role and voice of various stakeholders in a participatory design process?”

A stakeholder is a person or organization that the building configuration decision has a significant chance of affecting. In theory and in practice, we have often observed this role confused with the role of those with an ownership claim over the building (such as company shareholders). For example, Howard (2008 p.39) states, “It is useful to define a stakeholder in a decision as ‘someone who can affect or will be affected by the decision’”. Although shareholders are a prominent group of stakeholders, there are many more groups. We have found that project teams are often surprised by how many stakeholder groups a thorough analysis reveals. Additional stakeholder groups that we have often encountered for building projects appear in Table 1.

Table 1
Examples of Stakeholders

Builders	Maintenance Staff	Student Occupants
Donors	Neighbors	Staff
Designers	Press	Suppliers
Faculty	Residents	Utility Companies
Insurers	Student Non-Occupants	

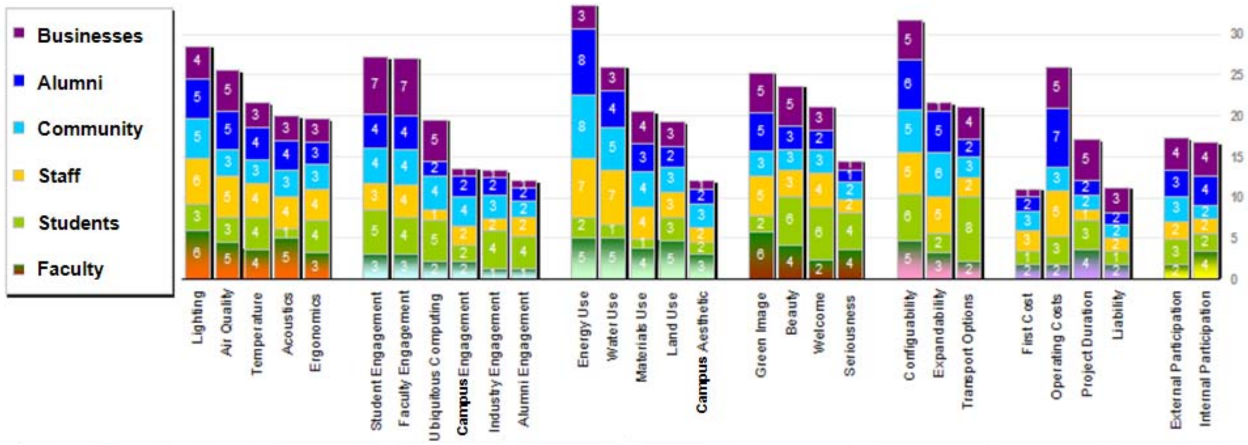
Objectives

A DDR should state the project objectives, which are the set of attributes that the building design may affect and that stakeholders may care about. According to Howard (1988), “clear values,” indicate which possible outcomes are preferred, and by how much. Typically, a building owner values some of these objectives directly (such as first cost) and some indirectly (such as project duration, which affects cost by delaying revenue-generating occupancy). A metric and description is associated with each objective. Explicit objectives enable tradeoffs in decision making methods in both traditional practice and in Decision Theory and Decision Analysis.

A DDR should also state how much different stakeholders care about each goal. However, none of the consultants we ethnographically observed used quantitative stakeholder objective valuation. Instead, engineers either relied on professional judgment (updated informally, if at all, based on perceived changes in demand) or inferred preferences from ordinal or rhetorical descriptions. Keeney and von Winterfeldt 2008 propose the notion of a practical value model based on decision context. “On any major decision, it is worthwhile to initially think of objectives from the viewpoint of various stakeholders concerned about a decision …Analysts can help by combining values expressed throughout the organization and by improving the communication of values within the organization” (Keeney and von Winterfeldt 2007 p. 247).

Value-focused thinking (Keeney 1992) provides a method of using goals as primary drivers of problem structuring, such as the generation of alternatives, which has been applied broadly in recent years (Keefer 2008). Nevertheless, challenges remain: “In architectural design and planning, due to broad social participation, design goals are many and often represent inconsistent and even conflicting desires and concerns. It is often difficult to clarify and understand the concerns of different parties, not to mention aggregating them into a single decisive option” (Cao and Protzen 1999 p. 347).

Figure 3
Examples of Stakeholder Objectives
Source: Haymaker et al. 2008



As Figure 3 shows, stakeholders affected by the construction of a new university campus communicated their objectives by distributing 100 points over the goals in a survey (not shown). More details of the study appear in Haymaker et al 2008.

This diagram communicates the results of the survey by stacking the average objectives reported for each stakeholder group. This is an example of independent objectives that state the amount of benefit that an organizational actor derives from satisfying a certain goal. The combination of all objectives related to an actor determines a utility function. There are two notable examples of insight from the diagram. First, the stakeholders assert that energy use is about twice as important as maintaining the “Campus Aesthetic,” although both are important goals. Second, lighting is an issue that is approximately twice as important to faculty as students. This one chart supports thousands of individual comparisons, each of which may be relevant to design decisions yet unlikely to filter through traditional communication channels to the designers and managers.

Altruistic preferences regard satisfaction of other stakeholders, rather than direct building effects. "Even when the decision maker is one person, that person may consider the consequences of the decision on other people" (Howard 2008 p. 39). As an important example, the building owner's wish to satisfy investors, residents, community, and other stakeholders may be the principal determinant in the final design choice. Unfortunately, "It is not possible to construct the definitive, normative group utility function…No methods exist for accurately comparing subjective preferences between individuals" (Thurston 2006b p. 131). Furthermore, "When one attempts to make the distribution of welfare (or level of satisfaction) among individuals more even or "fair," then one must sacrifice total group welfare (or in the case of design, overall design worth)" (Thurston 2006b p. 131). In spite of the difficulties, design decisions require developing a model of altruistic and direct objectives for all stakeholders and integrating those models into a single view of social welfare. Chachere and Haymaker explore further the project (2008a) and industry (2008b) implications of efforts to state the social welfare model.

Designers

A DDR should indicate what designers propose and analyze options in order to establish their legitimacy. Designers define building options and analyze those options regarding stakeholder objectives and constraints. Examples of building options that we have often encountered for building projects appear in Table 2.

Table 2
Examples of Building Options

Acoustics	Electrical	Parking
Architecture	Estimating	Plumbing
Architectural Detailing	Fire	Structural Engineering
Audio Visual	Interiors	Sustainability
Civil Engineering	Lighting	Waterproofing
Construction	Mechanical Engineering	Workplace Planning

Options

A DDR should provide options, judged by Howard as “creativity” in spanning “significantly different alternatives,” to identify the different possible designs. Options to choose among include possible building and subsystem technologies, such as the set of alternative sites, the viable building orientations, and the available structural materials. Emerging parametric modeling methods (Kolarevic, 2003) are assisting designers in generating these options quickly, and Building Information Modeling (Eastman, 2008) is assisting them to represent these options clearly.

Gatekeepers

A DDR should state the project’s gatekeepers, which are individuals and teams with the power to constrain the range of viable options. Gatekeepers typically include a diverse range of individuals and groups, such as those in Table 3. AEC design decisions are subject to many gatekeepers. These gatekeepers, alone or in combination, have the power to prevent a building project from going forward based on certain criteria. They can also act without trading off stakeholder preference in a utilitarian manner. Moran and Carroll (1996) ask, “How can we keep track of the assumptions made during the design process, many of which are implicit?” In particular, experienced teams share numerous assumptions regarding which options are viable, and documenting them in an explicit list of gatekeepers is fundamental in explaining the rationale for a building design.

Table 3
Examples of Gatekeepers

Board of Directors	Labor Union
Building Department	Occupational Health Authority (OSHA)
Chief Financial Officer	Planning Commission
Environmental Review Commission	Specialty Equipment Supplier
Fire Marshal	Specialty Material Supplier
Insurance Inspector	

Typically, building owners are the most prominently represented gatekeepers on the project team. Owners also select the options to execute, and sign paychecks. Often, several participants in the owner organization possess the power to veto an option.

Constraints

A DDR should state constraints. These are known conditions that are required for a design option to be selected and built. Hazelrigg (1996) defined constraints as higher-level design decisions that simplify decisions but actually serve as higher-level proxies for system-level objectives. "(There is a) range beyond which the decision-maker is no longer able and willing to make trade-offs" (Thurston 2006b p. 130). "(In design rationale,) a feature of a good design space analysis is that it clarifies the boundaries of a given possibility space" (Shum 1995 p. 205). Formally, a constraint is a logical statement that must hold for each option, but that does not affect valuation. Often models will include both a constraint and an objective regarding the same goal. For example, owners prefer to minimize cost, which is an objective, but are constrained to keep cost below the limited available budget.

Gatekeepers contribute information about constraints, and therefore constraints can be defined no more clearly than the gatekeepers are defined. A DDR should provide clear definitions of gatekeepers and their constraints as to frame "the right challenge," (as motivated by Howard 2008) and restrict attention based on the decision context. The constraints limit attention to the actionable set of decisions. They can establish higher-level choices (made in an earlier stage), forestall lower-level decisions (made in a later stage), and specify pragmatic, political, or legal requirements.

Analyses

A DDR should provide analysis, judged by Howard as "informational excellence," that identifies the implications of choosing each possible design option. An analysis is an assertion about the consequences of a particular building choice. An analysis relates an organizational actor providing the source of data (the designer), an option that the analysis regards, a goal according to which the analysis is performed, and the result of the analysis. Intuitively, the analysis provides a designer's assertion of how choosing an option will affect a previously identified goal.

A DDR's analysis also includes each option's viability, which is whether the option satisfies the design constraints. Options are viable if, and only if, they violate no constraints. A design rationale should also analyze each option's valuation, which is how the option would affect stakeholders. The combination of analyses and objectives determines valuation. Each option is valued according to how much stakeholders prefer the results that corresponding analysis predicts, and how much that stakeholder's utility is valued by the decision maker.

Analyses contribute information about how options relate to constraints and objectives. Therefore, analyses can be defined no more clearly than the constraints, options, and objectives are defined.

Rationale Clarity

Moran and Carroll (1996) ask, "How much design rationale should be made explicit?" A DDR should provide sufficient clarity to motivate adopting the choice of consensus, judged by Howard (2008) as "commitment to action." Teams need to know what clarity is, and where it is required. This clarity will help them develop consensus and broadly communicate the reasons behind any decision.

Teams vary in their ability and motivation to clarify rationale components. As a result, projects achieve different conditions of clarity in their components. In order to compare the project rationales developed by these projects, participants require a language for describing the conditions of clarity they achieve in each component.

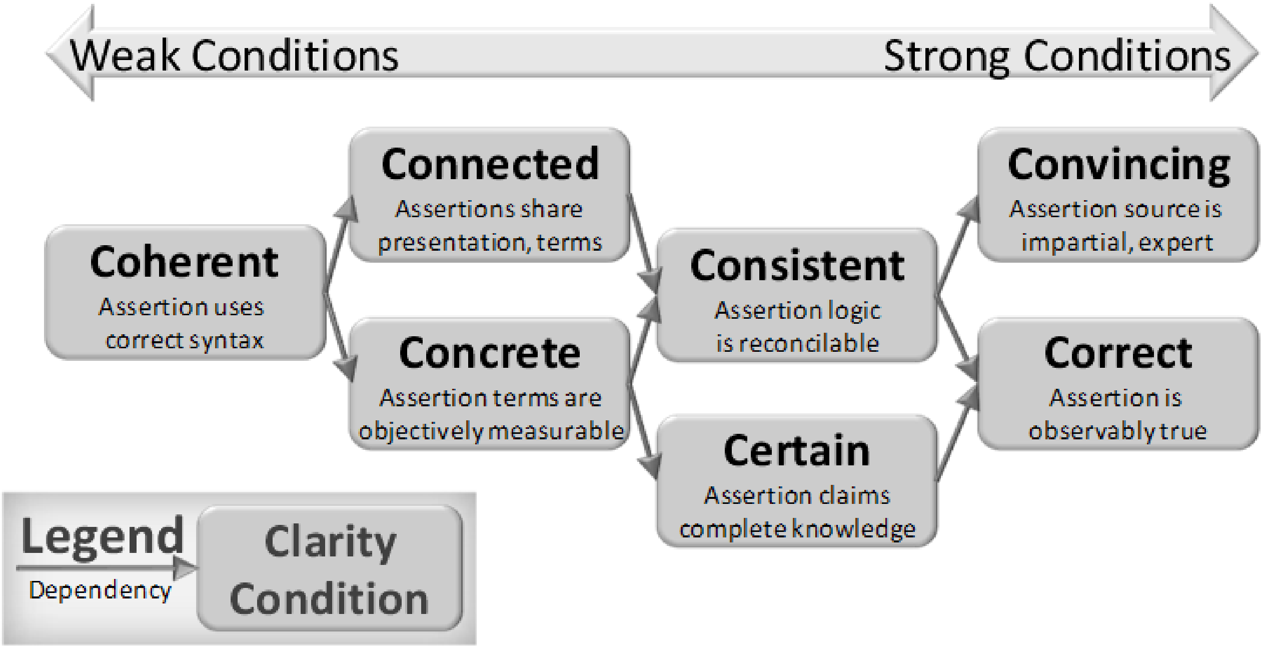
For example, design teams who specialize in analyzing building performance using computer models can achieve clear analysis of building options. However, such a team may achieve less clarity in stating objectives, and present only a partial list of performance targets. Clearly understanding the details of building performance, without clearly grasping their significance regarding objectives, results in an unclear overall rationale to support building decisions. The assertion with the least clarity determines the overall clarity of a Design Decision Rationale (DDR).

Definitions of Clarity of a Rationale

The notion of clarity measures the information conveyed in atomic portions of DDR called assertions. An assertion is an indivisible part of a rationale that some member of the project presents. Each assertion contains information regarding a DDR component, such as constraints, analyses, and objectives. Each assertion typically achieves some, but not all, definitions of clarity. For example, a structural analysis may contain the assertion, "The steel structure will cost less than $10M to build." The assertion is clear about the amount of money, and clear about the option being analyzed. However, it is unclear about who is providing the cost analysis. Therefore, the assertion is unconvincing, and may be incorrect.

Figure 4 introduces RCF's conditions of clarity, their summary definitions, and dependencies between the conditions. This section defines several clarity conditions that design rationale assertions can achieve: coherent, concrete, connected, consistent, convincing, certain, and correct. Ideally, teams would develop DDRs meeting all these criteria, in all rationale components, to collaboratively produce a design decision. However, since teams have limited knowledge and time, the assertions comprising their DDR typically do not achieve all conditions of clarity. Generally, a team should be able to produce a convincing rationale. However, most teams fall short of that target because their assertions are unclear or absent in key rationale components.

Figure 4
Rationale Clarity Conditions, Definitions, and Requirements



To introduce the conditions of clarity, consider the following assertion by a structural contractor regarding the structural decision rationale's analysis component: "The modeled steel structure's materials will cost $10M."

1. *Is the assertion coherent?* Yes, it is *coherent* because it is grammatically correct. By contrast, the assertion "Will cost $10M" does not indicate the assertion's subject and is therefore *incoherent.*
2. *Is it the assertion concrete?* Yes, it is *concrete* because it identifies the exact structure and dollar amount. Merely stating that the structure will be "expensive" would be *vague.*
3. *Is the assertion convincing?* Yes, it is *convincing* because it comes from an expert on the subject. Coming from an electrical contractor, the above assertion would be *unconvincing.*
4. *Is the assertion connected?* Yes, it is *connected* because it relates to an existing model of the steel structure. If there were no modeled steel structure, the above assertion would be *disconnected.*
5. *Is the assertion consistent?* Yes, it is *consistent* because this is the only assertion relating structural costs. A second assertion that the total structural cost will cost $9M would render the above assertion *inconsistent*.
6. *Is the assertion certain?* Yes, it is *certain* because it represents the utmost confidence regarding the cost. Stating that the steel price is equally likely to be $9M or $10M, based on market price fluctuations, would be *uncertain*.
7. *Is the assertion correct?* Yes, it is *correct* because it turns out the materials cost $10M. If the steel cost totaled $11M, the above assertion would be *incorrect*.

Although each clarity condition measures a different criterion, failing to meet some criteria renders assessing other criteria impossible. For example, assertions must be coherent to meet any other criteria, and they must be both concrete and connected to be evaluated for consistency. Therefore each assertion achieves the seven distinct conditions of clarity to one of thirteen different levels.

Table 4 presents those combinations and offers summary terms used to tersely distinguish them.

Table 4
Levels of Clarity and Associated Conditions

Clarity Conditions Satisfied	Level #	Shorthand Term
<none>	0	Incoherent
coherent	1	coherent
coherent, connected	2	connected
coherent, concrete	2	concrete
coherent, concrete, certain	3*	certain
coherent, concrete, connected	3	connected
coherent, concrete, connected, certain	4*	connected certain
coherent, concrete, connected, consistent	4	consistent
coherent, concrete, connected, consistent, certain	5*	consistent, certain
coherent, concrete, connected, consistent, convincing	5	convincing
coherent, concrete, connected, consistent, certain, correct	6*+	correct
coherent, concrete, connected, consistent, convincing, certain	6*	convincing, certain
coherent, concrete, connected, consistent, certain, convincing, correct	7*+	convincing, correct

* Assertions regarding fundamentally uncertain (e.g., random) events cannot achieve this level of clarity
\+ Assertions regarding fundamentally unknowable (e.g., future) events cannot achieve this level of clarity

The following sections detail each clarity condition, explaining definitions, dependencies, and examples.

Coherent/Incoherent

Coherent assertions obey the most basic rules that communications media require to convey meaning. For example, coherent rhetorical statements obey the grammar of a natural language, coherent mathematical formulas are well-formed, and coherent computer algorithms are syntactically correct (i.e., they compile).

Table 5
Examples of Incoherent Assertions

Component	Incoherent Assertion
Manager	"The Project Manager"
Stakeholder	"Neighbors"
Objective	"Green building"
Designer	"A. Corp."
Option	"Steel"
Gatekeeper	"Firemen"
Constraint	"Must resist fire"
Analysis	"The steel structure's materials"

In practice, incoherent assertions commonly result from assuming readers possess and will apply specific background knowledge. For example, we often observe blank spaces in analysis matrices such as Figure 1 (on page 4). Unless there is an accompanying explanation, this practice is equivalent to stating, "The option's effect on the goal is." Readers can interpret these blank spaces to mean the corresponding analysis was not conducted, was not applicable, resulted in a prediction of an option having zero effect on a building, or was erroneously omitted. Table 5 provides an incoherent claim regarding each rationale component. All of the assertions in Table 6 are coherent.

Concrete/Vague

Assertions that are coherent may be concrete enough to convey objective meaning, or may be open to subjective interpretation. Concrete assertions state data in explicit terms requiring no additional project knowledge to understand. Exactly those distinctions meeting the "clarity test" from decision analysis meet this definition of concreteness (Howard 2008). By contrast, assertions that (to the source) seem conventionally understood, but have no concrete definition, allow for misinterpretation. Table 6 provides one example of a vague assertion for each rationale component.

Table 6
Examples of Coherent but Vague Assertions

Component	Vague Assertion
Manager	"The Project Manager will choose"
Stakeholder	"Neighbors are affected"
Objective	"Energy efficiency is an objective"
Designer	"A. Corp. will supply engineering design"
Option	"Steel can provide the building structure"
Gatekeeper	"Firemen must approve the building"
Constraint	"The building must resist fire"
Analysis	"The steel structure's materials are expensive"

Only coherent data can be defined as either concrete or vague; in a sense, incoherent assertions are objectively identifiable as a complete failure to communicate, whereas vague assertions do carry information that is are vulnerable to subjective interpretation. As an example, the assertion, "The steel structure's materials cost $10M" is concrete because the exact cost of materials can be objectively determined and compared with $10M. In contrast, the assertion, "the steel structure's materials are expensive" is vague because people may view the materials as expensive when comparing to the building's other structural option, but as inexpensive when comparing to steel used for another building.

Connected/Disjoint

Multiple coherent assertions that share common terms and presentation are termed connected. Connected assertions relate data directly and meaningfully to other assertions, without requiring additional analysis, insight, or expertise. Typical design documents contain many connected assertions in rhetorical, tabular, or visual formats. Table 7 shows assertions that teams often connect, with corresponding sources for both connected and disjoint cases (assertions from multiple components are more often disjointed.

The definition of rationale clarity includes a notion of connectedness between data because decision making requires assertions' synthesis. Making implicit knowledge explicit is necessary for integrating multiple perspectives into a single decision basis. Narratives (Haymaker 2006) provide one generic means for representing the connections between multiple sets of information.

Consistent/Contradictory

Any set of connected, concrete assertions can be evaluated for consistency. Consistent assertions are mutually compatible; no reasonable interpretation can support contradictory assertions. For example, the assertions, "The Master Suite will be on the second story" and, "The residence will have only one story" are contradictory. Table 7 provides additional examples of consistent and inconsistent assertions.

Table 7
Examples of Concrete Assertions,
Comparing Consistent with Inconsistent and Connected with Disjoint

Component	Source 1	Assertion 1
Manager	Owner's CEO	"The Project Manager's (PM) design choice is final…"
Stakeholder	Neighborhood Association	"Residents outside ½ mile never care about the design…"
Objective	Project Manager	"1 kW energy efficiency is worth $1K to the owner…"
Designer	Project Manager	"A. Corp. will provide mechanical options…"
Option	Structural Contractor	"A steel rocking frame can provide building structure…"
Gatekeeper	Building Inspector	"The Fire Marshal must approve the final design…"
Constraint	Building Inspector	"Design must allow safe exit after 8.5 magnitude quake…"
Analysis	Structural Contractor	"The steel structure's materials cost $10M…"

Component	Disjoint Source 2	Consistent Assertion 2	Inconsistent Assertion 2
Manager	Project Manager	"…and the owner CEO will support the PM design choice."	"…and the owner CEO can override the PM design choice."
Stakeholder	City Council	"…and residents outside ½ mile do not care about the design."	"…and residents outside ½ mile do care about the design."
Objective	Operations Manager	"…and worth $10 average to the maintenance staff."	"…and worth less than $100 to the owner."
Designer	A. Corp. CEO	"…and A. Corp. will provide structural options."	"…and B. Corp. will provide mechanical options."
Option	General Contractor	"…and a steel rocking frame can provide building structure."	"…and a steel rocking frame can not provide building structure."
Gatekeeper	Insurance Representative	"…and the Building Inspector must approve the final design."	"…and only the Building Inspector must approve the final design."
Constraint	Structural Contractor	"…and withstand a 8.0 quake."	"…and withstand a 9.0 quake."
Analysis	Project Manager	"…and the steel structure's total costs are $18M."	"…and the steel structure's total costs are $8M."

Only connected data can be considered consistent. Disjointed data cannot be compared to ascertain where any contradictions may lie. Additionally, only concrete data can be consistent or inconsistent. To the extent that an assertion is vague, it carries no objective meaning that relates to other assertions. For example, the assertion, "The steel structure's materials cost $10M. Labor raises the total cost of the steel structure to $8M" is contradictory because $8M is less than $10M. In contrast, the assertion, "The steel structure's materials cost $10M. Labor raises the total cost of the steel structure to $18M" is consistent for labor costs of $8M.

Convincing/Dubious

Assertions that are both concrete and consistent may be convincing, in the sense that they depend on a notion of legitimacy. For an assertion to be convincing, it must come from a source that has credentials to indicate knowledge of the subject. The source must also be trusted to deliver assertions free from bias.

Table 8 provides several examples of sources that would make different assertions convincing or dubious. Only consistent assertions can be stated convincingly because it is illogical to believe in both sides of an unresolved debate.

Convincing assertions reflect the highest degree of belief achievable without experimentation. Convincing assertions are those management views as legitimate, typically because they have been confirmed by people or organizations broadly viewed as experts in that particular domain. Typically, management-designated designers provide convincing options, management-designated stakeholders (or their elected representatives) provide convincing objectives, and gatekeepers responsible for enforcing constraints provide convincing constraints.

Table 8
Examples of Dubious and Convincing Sources for Assertions

Component	Convincing Source	Dubious Source	Assertion
Manager	Owner's CEO	Project Manager	"The Project Manager will choose the final design"
Stakeholder	Neighborhood Association	Owner's CEO	"Residents within ½ mile care about the design"
Objective	Project Manager	Structural Contractor	"1 kW energy efficiency is worth $1K to the owner"
Designer	Project Manager	Fire Marshall	"A. Corp. provides structural and mechanical options"
Option	Structural Contractor	Electrical Contractor	"A steel rocking frame can provide building structure"
Gatekeeper	Builder	Neighborhood Association	"The Fire Marshal must approve the final design"
Constraint	Fire Marshal	Neighborhood Association	"The building must meet local, state, and federal fire codes"
Analysis	Structural Contractor	Electrical Contractor	"The steel structure's materials cost $8M"

Each assertion has a source who is an organizational actor. That actor may be an individual or a team, and includes associated facilities or information technologies. The logic provided here does not distinguish between actors who are individuals speaking for themselves or teams speaking based on the authority for their organization. However, extending the logic to support additional reasoning is straightforward.

Certain/Uncertain

Assertions that are coherent may report facts using certain terms, such as "the soil is sandy," or using uncertain terms, such as "an earthquake might strike." Furthermore, assertions that are concrete can usefully convey uncertainties concretely with Bayesian probabilities; "Assigning probabilities to distinctions that (are vague) is an exercise in futility" (Howard 2008 p.39).

Table 9 provides examples of uncertain assertions, which express a limited amount of knowledge regarding events' likelihood. Whereas convincing assertions reflect the greatest practically achievable degree of belief, certain assertions claim absolute knowledge of whether an attribute holds or whether an event will occur (or has occurred).

Table 9
Examples of Uncertain, Coherent, Vague / Concrete Assertions

Component	Vague Assertion
Manager	"The Project Manager's design choice probably / 75% is final"
Stakeholder	"Residents outside ½ mile probably / 75% care about the design"
Objective	"1 kW energy efficiency probably / 75% is worth <$1K to the owner"
Designer	"A. Corp. probably / 75% provides structural and mechanical options"
Option	"A steel rocking frame probably / 75% can provide building structure"
Gatekeeper	"The Fire Marshal probably / 75% must approve the final design"
Constraint	"The building probably / 75% must meet local, state, and federal fire codes"
Analysis	"The steel structure's materials probably / 75% will cost $8M"

The first type of uncertainty, known as aleatory, regards facts that are unknowable due to fundamentally random processes. For example, "There is a 10% chance that a magnitude 8.5 earthquake or larger will strike the building within the next 30 years" is a concrete assertion that communicates an aleatory uncertainty. In the case of aleatory uncertainties, methods including experimentation and consultation with additional experts may reduce, but cannot eliminate, uncertainty. Therefore correctness, as defined below, may not be achievable. For example, assessing a coin flip that has not yet occurred may be defined as reaching the highest achievable level of confidence, if stated with equal chances of heads or tails, rather than as the uncertain prediction of heads (or of tails), because the future result of a coin flip is unknowable.

The second type of uncertainty, known as epistemic, regards matters of fact about which we have limited knowledge. For example, "There is a 10% chance the soil at the building site is sandy" is a concrete assertion that communicates an epistemic uncertainty. In the case of epistemic uncertainties, methods including experimentation (such as geologic testing) and consultation with additional experts may reduce or even eliminate uncertainty (therefore enabling correctness, as defined below).

Assertions that include uncertainties are not considered contradictory simply because they result in unlikely conclusions. For example, "There is only a 0.1% chance of an 8.5+ magnitude quake this year," does not contradict "a 9.0 magnitude quake occurred this year" because there is an interpretation that supports both assertions (namely, that an unlikely but possible event has occurred).

Correct/Incorrect

Assertions that are both consistent and certain may be either correct or incorrect. Correct assertions are true in an absolute sense, meaning they are consistent with all other correct assertions; Contradictory data must contain at least one incorrect assertion. Although correctness is often difficult to assess, developing a rationale involves attempting to increase the degree of correctness by checking assertions' consistency against other certain assertions. Table 10 provides an example assertion for each rationale component and results that would render each assertion either correct or incorrect.

Table 10
Examples of Certain Assertions and of Results if Correct or if Incorrect

Component	Certain, Concrete Assertion	Result if Correct	Result if Incorrect
Manager	"The Project Manager's design choice is final"	"actually is built"	"was overridden"
Stakeholder	"Residents outside ½ mile don't care about the design"	"actually don't care"	"actually do care"
Objective	"1 kW energy efficiency is worth $1K to the owner"	"is actually worth $1K"	"is actually worth $1.5K"
Designer	"A. Corp. will provide structural & mechanical options"	"did actually provide"	"did not provide"
Option	"A steel rocking frame can provide building structure"	"can actually provide"	"cannot provide"
Gatekeeper	"The Fire Marshal must approve the final design"	"must actually approve"	"need not approve"
Constraint	"The building must meet local, state, & federal fire codes"	"must actually meet"	"need not meet"
Analysis	"The steel structure's materials will cost $10M"	"actually cost $10M"	"actually cost $11M"

Under this definition, all correct data is also certain. Fundamentally random (aleatory) uncertainties, like coin flip outcomes, can eventually be determined correct or incorrect. However, a probability distribution on outcomes cannot be determined correct or incorrect. For example, the occurrence of an 8.5 magnitude quake neither confirms nor negates the uncertain assertion "30% chance of magnitude 8+ quake within 20 years." This definition of correctness agrees with the view of classical statistics (although not with views of quantum physics). Even aleatory uncertainties, like coin flip outcomes, are simple facts that can eventually be learned.

CONCLUSIONS

Design rationale is complex and fragile, and is typically understood and managed poorly in practice. This paper reviewed existing literature relevant to the measurement of clarity in AEC Design Decision Rationale, and found no existing definition could portray the clarity of, and dependencies between, organizational actors and decision basis elements. The paper provided such a definition, the Rationale Clarity Framework (RCF), that views each relevant design assertion in two ways. First, what component of the rationale does the assertion address, such as objectives, constraints, or options? Second, what conditions of clarity does the assertion sustain, such as coherence, concreteness, and convincingness? A complete rationale includes assertions addressing each component, and a clear rationale includes assertions that meet the conditions.

DISCUSSION

We have found that conceptualizing project information using the rationale clarity framework exposes the contributions and deficiencies in existing decision rationale documentation methods, and may create a unified view suitable for developing organizational consensus within AEC organizations to improved process and product performance. This section discusses implications of the RCF for research and practice.

Implications for Research

A standard definition of rationale clarity can improve the ability of researchers to compare theories and methods, and enable the formulation of testable propositions regarding the effects of increasing clarity on AEC projects and industry.

Chachere and Haymaker (2008a) use the RCF to explore the manifold and subtle causes and effects of clarity on project performance. Managing consensus on novel building design processes is difficult because industry tradition engenders self-interested behavior by project participants and discourages designs deviating significantly from precedents. Whereas a traditional decision analysis provides a structured conversation leading to clarity of action, we have observed that the system of checks and balances in AEC design projects requires a structured collaboration leading to consensus of action. The paper presents a set of propositions about the potential effects that using a clear rationale may have on the project and industry. This paper uses theories of organization, social psychology, management, and management science to form a theoretical argument that building and maintaining consensus in AEC design using a rational, explicit, socially constructed design rationale is possible and tends to improve outcomes. The paper concludes with a discussion of findings from several ethnographic and intervention studies. These findings support the hypothesis that improvements to the exploration and evaluation of design spaces, and to consensus management, justify socially constructing clear, decision-based design rationale models in AEC.

Chachere and Haymaker (2008b) use the RCF to explore the manifold and subtle causes and effects of clarity in the AEC industry. In recent years, stakeholder concerns, building codes, and building products have become more dynamic than historically, tracking (for example) increased attention to sustainability, security, extreme weather, information technology, and globalization. The paper describes how these issues have undermined projects' once-valid justification for professionalization, creating an opportunity for disruption by alternate methods of rational administration. In particular, bureaucratizing AEC projects becomes more compelling with the availability of methods that assess novel conceptual designs more clearly and rationally. These observations and existing theories suggest that a combination of contemporary industry challenges (such as supply-chains and competition, new building technologies, and rapidly dynamic project goals) will lead to a period of turbulence and the need for re-organization. The paper argues that the US industry needs to adopt methods of clarifying rationale to assess and adapt to changes in product, organization, process, and technology.

Haymaker et al (2008) provide a case study that uses the RCF to assess the effects of implementing a formal decision support method (the same method applied in Haymaker and Chachere, 2006). The paper uses the DDR clarity framework to assess the effectiveness of clarifying design rationale on the design of a university campus building. The formal model tracks the project team's efforts to clarify components and relationships through conditions of clarity. Marking field observations at their corresponding locations in a visual representation of rationale clarity helps identify and explain weaknesses in the project's development and communication of AEC design rationale. The paper then uses the framework to guide construction of a new model that attempts to clarify rationale for the same design decisions. The paper concludes with a discussion of observed and potential importance for design decision making processes including causes and effects of clarity for projects and for industry.

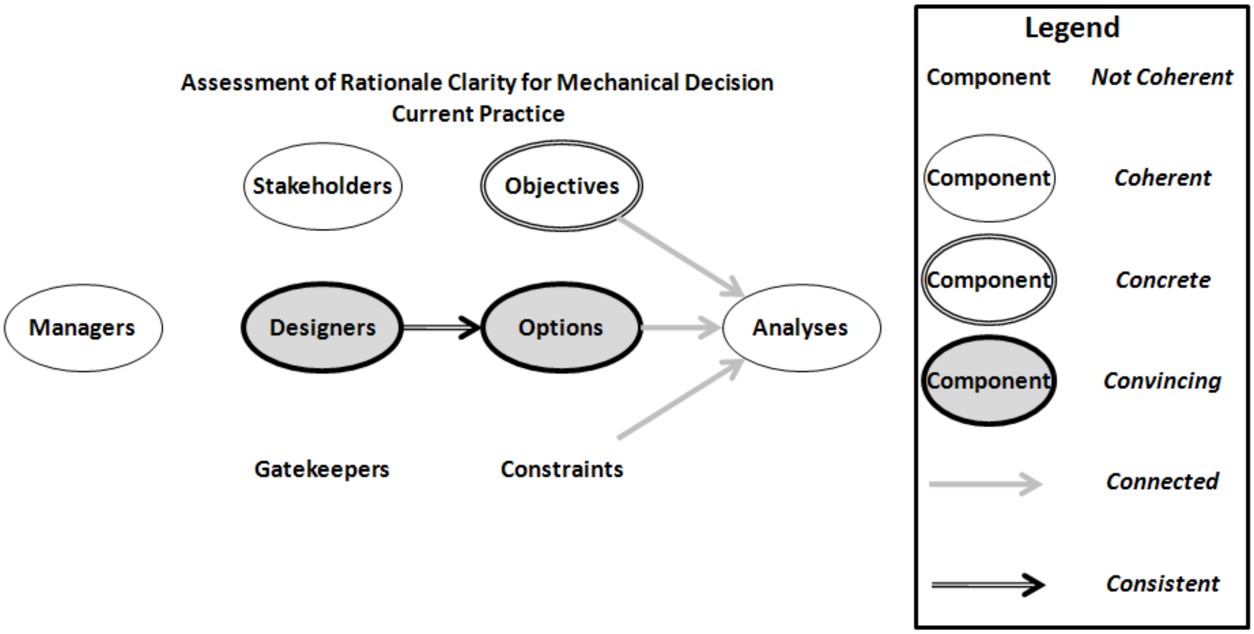
Implications for Practice

In general, developing a perfect design rationale is neither possible nor desirable (Fischer et al. 1991). However, the formal model of clarity identifies some of the implications of these gaps in rationale. Projects typically adopt a wide range of methods to clarify different components to varying degrees. The analysis in this paper indicates that to achieve clarity in the analysis, however, projects ought to spend their limited resources in a balanced fashion, advancing each of the components to an equally high level of clarity. A decision-based design rationale should provide efficiency in the use of decision resources, judged by Howard (2008) as “balance of basis,” and similarly, the design decision rationale’s strength equals the strength of its weakest link. This metaphor extends the six-link model of decision analysis quality provided by Spetzler (2008). For example, an analysis cannot be convincing if the set of objectives are not convincing, or if any of the elements are inconsistent.

The process of measuring rationale clarity for a specific project consists of breaking down project documentation into individual assertions, evaluating their clarity, and reporting the aggregate levels of clarity in each component and in the overall rationale. This paper provides several interrelated conditions that set varying standards for clarity, so that each assertion, component, and the total rationale will surely meet some, but not all clarity conditions.

Deeply understanding the state of rationale development can be difficult because each project’s wide array of assertions incorporates myriad regions of clarity and ambiguity. Once definitions of rationale components and clarity have a common definition, their practical use during a fast-paced project motivates mapping the DDR clarity. For example, Haymaker et al. 2008 uses RCF to report the rationale clarity obtained by a university campus project before and after intervening to clarify rationale. Figure 5 presents the conditions of clarity observed in the interdependent decision components based on traditional practice. In the study, additional maps describe a structural system decision and describe both decisions after implementing a decision support and rationale clarification tool.

Figure 5
Assessment of Rationale Clarity from a Case Study
Source: Haymaker et al. 2008



A similar map organizes existing theories and new propositions relevant to the interrelated components of rationale in Chachere and Haymaker 2008a, and another map organizes observed and forecast trends in the AEC industry in Chachere and Haymaker 2008b. Our hypothesis, to be tested in future work, is that comparing individual project maps with maps of organizational theory and strategy can facilitate recognizing opportunities for cross-validation of theory based on practice and for the application of theory by practitioners. The key to navigating contemporary turbulence may be this increased awareness of project and industry dynamics (Chachere and Haymaker 2008a, 2008b).

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