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Analyzing Design Workflow: An Agent-based Modeling Approach

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Abstract

Variability embedded in the architecture, engineering, and construction industry often results from inefficient planning strategies, sub-optimal levels of coordination, and poor flow of information and resources. This inherent variability disrupts workflow in design, results in longer cycle times, increased costs, and rework; thus undermining design, as well as, construction performance. This paper addresses design workflow at the intersection of the social and process aspects of the design phase. These aspects have been studied separately in previous research works, which prevented capturing a comprehensive and realistic understanding of the design process. Accordingly, this study develops a new approach to qualitatively and quantitatively model the exchange of information between design players and pave the way to assessing the impacts of Building Information Modeling and new project procurement strategies on improving design workflow. Agent-based modeling is used to dynamically represent the relationship between social interactions and the diffusion of information between individuals and teams. The study presents a novel design workflow management approach that bridges the gaps in previous studies as it focuses on team structures, interaction dynamics, and information diffusion.

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1. Introduction

Design workflow can be defined as the flow of information, deliverables, specifications, and other design resources between the right people at the right time. Maintaining a smooth flow of design information is key to a value adding transformation of design input into the client's proposition. However, designers, planners, engineers,

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and constructors only focus on the transformation process, from input to output, ignoring what happens within the vague box of transformation. While poor flow of information and design errors plague the design process resulting in delays, increased cost, and compromised design quality, available literature address such issues without an in-depth study of inherent problems in design communication networks and behaviors. Traditional planning and management methods applied during design do not consider workflow or the drawbacks of variability. Variability embedded in the architecture, engineering, and construction (AEC) industry often results from inefficient planning strategies, sub-optimal levels of coordination, and poor flow of information and resources. This variability disrupts workflow, results in longer cycle times, increased costs, and rework; thus undermining design and construction performance [1, 2].

In fact, perceiving the design process as a flow of information rather than a rigid segmentation and sequencing of design tasks can lend itself to a better design management approach [3]. Such conceptualization is the foundation to finding ways to reduce the time information that is queued before it is used, minimize time spent on reworking design information to meet requirements, and avoid unnecessary overproduction of obsolete data. More importantly, this perspective of design as information flow is crucial for the integration and coordination of multi-disciplinary information at a current time of increasing design complexity, sophisticated client needs, and a rapid proliferation of information from multiple geographically dispersed teams. With the presence of different project procurement approaches that call for more collaboration among project teams, and with the utilization of modern technologies, namely Building Information Modeling (BIM), the need to evaluate their impacts on design workflow and compare their performance to more traditional delivery approaches calls for a new perspective to better understand design workflow. Although defining what better design management entails and how workflow should ideally be, a practical analysis of workflow characteristics and the influence of human interactions that shape these workflows in the context of BIM-based design processes and collaborative deliveries have not been considered or examined.

In this regard, the design phase should be conceptualized as the intersection of a social organizational structure and the involved dynamics of information exchange. The integration of these segregate approaches remains absent resulting in incomprehensive analytical methods that fail to capture a realistic image of information flow within design networks. In this respect, this study first highlights some limitations in the current analytical methods and proposes a novel approach that uses agent-based simulation for modeling information flow within social network topologies of team coalitions. Potential implications of this approach are then introduced.

2. Gaps in existing methods for workflow analysis

Existing analytical methods tend to separate the topology of team interactions from the flow of information by focusing solely on design task transformation while neglecting the flow of design information, or by only considering the structural setup of involved individuals and ignoring information diffusion, or by analyzing information diffusion and ignoring team coalitions. Some gaps in the current body of research and practice are presented below:

- The role of information flow between designers is not broadly considered in research and the industry, which results in poor workflow practices. Informal surveys conducted with design teams revealed that negative iterations (rework) constitutes an approximate 50% of design time [4]. This rework can be a result of obsolete or missing information that was not promptly shared. In practice, individuals and teams work in isolation without realizing that information they are withholding is useful for other team members and the overall design requirements.
- The negative impacts of poor design workflow are not fully understood which limits the incorporation of flow into actual practice. Some studies have developed flow diagrams to qualitatively map the flow of design deliverables through different stages of the design process [5]. However, this flow has not been mapped across multi-disciplinary teams to highlight the interactions between trades with different design needs and outputs. Therefore, the impact of such multi-disciplinary relationships on information flow was not thoroughly assessed.
- The existing frameworks for the quantification of flow metrics are incomplete and insufficient, which makes it hard to measure performance on design projects. Measuring performance is an important step to assess design workflow and implement the required changes. A few studies were targeted towards measuring design

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