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# ESTABLISHING RESEARCH METHODS FOR 3D CONCRETE PRINTING SUPPLY CHAIN STUDIES: INSIGHTS FROM LITERATURE AND PRACTICE

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As digital construction technology, 3D printing is reshaping the construction sector by reducing costs and improving efficiency. Its supply chains differ from traditional models and require redesign. However, research on enhancing supply chain efficiency in 3D concrete printing remains limited. Building on a previous systematic review conducted as part of the PhD study, this study discusses research methods, data collection techniques and analysis methods, and establishes a research methodology for developing a practical supply chain decision-making tool in 3D printing construction. It follows the systematic review findings to design the research program, integrating theoretical knowledge with practical applications. The study also reviews research methods to identify suitable approaches for data collection and analysis, as well as outcome validation. The results presented a comprehensive research design for developing the decision support tool. This research connects systematic review and data analysis, enabling a coherent interpretation of the overall research program. The final outcomes are expected to improve 3D printing projects' efficiency, facilitate the adoption of the technology in the construction sector, aligning with SDG 9, promoting inclusive and sustainable industrialization.

*Keywords*: Decision making, Decision support tool, Digital construction, SDG 9.

## 1 INTRODUCTION

Digital construction technologies, such as 3D printing, have transformed the construction industry by reducing costs, time, and material waste (Wu *et al.* 2018). Applied 3D printing can cut material costs by 35–60% and is effective for complex designs and remote construction (Teixeira *et al.* 2023). However, its immature application introduces uncertainty, and improper use may reduce efficiency (Olsson *et al.* 2021). Research highlights the need to enhance 3D printing implementation efficiency (Beltagui *et al.* 2023, Teixeira *et al.* 2023). Moreover, integrating 3D printing disrupts traditional supply chain structures, and organizational complexities further challenge management innovation (Singh *et al.* 2023). Thus, effective supply chain and decision-making are essential to improving efficiency and mitigating risks (Badi and Murtagh 2019).

Decision-making is central to management, and effective methods provide timely, reliable solutions. As 3D printing advances in construction, decision-making tools are essential for improving supply chain efficiency and supporting broader adoption (Stević *et al.* 2022). This paper presents the research methodology for developing a decision-making tool tailored to 3D printing construction supply chains. While existing studies use literature reviews, case studies, interviews, and Multi-Criteria Decision-Making (MCDM) methods to explore challenges and benefits, many

rely on literature-based criteria, limiting practical relevance (Wu *et al.* 2020, Ma *et al.* 2024). This study proposes a holistic research design that integrates academic methods with industry input, establishing a robust foundation for the ongoing research program.

## 2 LITERATURE REVIEW

This section reviews studies discussing common methods in 3D concrete printing and supply chain studies, integrating insights from a prior systematic review (Ma *et al.* 2024).

### 2.1 Data Collection Approaches

Data collection methods involve qualitative and quantitative methods. Quantitative methods assess the impact of additive manufacturing on supply networks (Barz *et al.* 2016) and analyze its benefits (Aghimien *et al.* 2020). Qualitative data collection methods allow the development and understanding of important supply chain management and implementation insights (Zimon *et al.* 2019). Luomaranta and Martinsuo (2020) utilized an exploratory qualitative research method to investigate the supply chain innovations within additive manufacturing.

Table 1. Data collection methods in existing 3D concrete printing studies.

| Author | Method | Purpose |
|---|---|---|
| Wu *et al.* (2018) | Questionnaire survey | Investigate the impacts of 3D concrete printing adoption |
| Aghimien *et al.* (2020) | Questionnaire survey | Assess the benefits and barriers of 3D printing adoption |
| Kothman and Faber (2016) | Interview | Discuss the feasibility and industry adoption of 3D concrete printing |
| Luomaranta and Martinsuo (2020) | Interview | Map 3D printing activities and explore supply chain innovations |
| Bazli *et al.* (2023)<br>Besklubova *et al.* (2023) | Case study | Evaluate existing systems, knowledge applications, and the feasibility |

The methods in Table 1 extract essential information to build research foundations (Bag *et al.* 2021). Structured questionnaires enhance efficiency by having experts participate in the data collection without making guesses in open-ended questionnaires (Liu and Lin 2021). Accurate interviews and interviewee perspectives contribute to effective data acquisition and analysis (Liu and Lin 2021). Whereas qualitative literature-based criteria extraction remains prevalent (Shojaei and Bolvardizadeh 2020). This matter resulted in a controversy where Wu *et al.* (2020) proposed using a model to identify and analyze potential alternative criteria quantitatively.

### 2.2 Data Analysis Techniques

In construction supply chain management studies, analytical modelling (Holmström *et al.* 2019) and MCDM methods are the most adopted approaches for data analysis (Rane *et al.* 2021). MCDM methods are typically applied to rank and conceptual research factors (Rane *et al.* 2021), thereby helping to propose the best solution in the decision-making process (Stević *et al.* 2022). Singh *et al.* (2023) support that MCDM methods are well-suited for addressing complex dilemmas that involve diverse perspectives and conflicting assessments. They utilized advanced MCDM methods to identify barriers that hamper the adoption of blockchain within construction supply chain management (Singh *et al.* 2023). Other methods, such as the Delphi method and rank-based nonparametric test, are also effective in examining the statistical differences in interviewees' responses (Wu *et al.* 2020, Wuni and Shen 2020).

There are various MCDM methods, including the Analytic Hierarchy Process (AHP), Technique of Order Preference Similarity to the Ideal Solution (TOPSIS) method, Fuzzy Cognitive Map, etc. (Figure 1). AHP is to analyze the distribution of a goal among elements and judge their influence on the goal (Rane *et al.* 2021). It gives weights or ranks to a Likert scale study components and a paired comparison among them, demonstrating the assigned components' significance (Singh *et al.* 2023). The TOPSIS method can be used to select the alternative that most closely approximates the ideal solution (Rane *et al.* 2021). Stević *et al.* (2022) adopted the fuzzy SWARA method to analyze the objective criticism, followed by fuzzy MARCOS to rank a set of alternatives. The MCDM methods can also be combined in data analysis. For example, Iqbal *et al.* (2023) applied the AHP-TOPSIS method to identify solutions to reduce barriers, assess identified risks, and rank criteria. Shojaei and Bolvardizadeh (2020) adopted rough TOPSIS and WASPAS methods using criteria identification and experts' opinions extraction to develop a decision-making model for supplier selection. They suggested incorporating other decision-making techniques, such as ANP and Fuzzy Cognitive Map, to deal with interdependent criteria (Shojaei and Bolvardizadeh 2020).

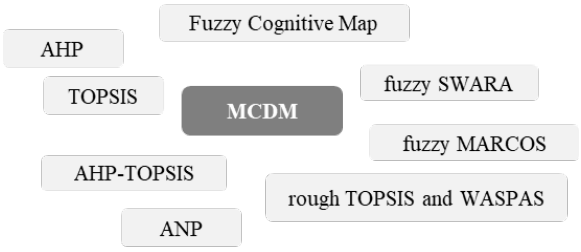


Figure 1. Key analysis methods of multi-criteria decision-making.

## 3 RESULTS AND DISCUSSIONS

The study explores the research methods for an ongoing PhD project in 3D printing construction supply chain management. The prevalent research methods are identified from existing studies in the construction supply chain and 3D printing sectors. Many analytical techniques are accessible for analyzing the collected data, and MCDM methods gain the most concern in investigating supply chain management issues (Rane *et al.* 2021, Stević *et al.* 2022, Singh *et al.* 2023).

### 3.1 Research Design and Methods Adoption

To develop a robust decision-making tool for 3D printing supply chain management, four objectives are proposed. The first is to study the significance of 3D concrete printing in construction supply chain management. Secondly, investigate 3D printing implementation and supply chain management challenges, and thirdly, generate a decision support system for supply chain decision-making. Finally, the research outcome will be validated.

#### 3.1.1 *Systematic review*

The research program begins with a systematic review, identifying existing 3D concrete printing implementation and supply chain challenges (Ma *et al.* 2024). This review critically analyses existing knowledge, highlights the need for technology adoption and supply chain innovation, and identifies research gaps. A key contribution is the proposal of a decision support system demo (Ma *et al.* 2024). The results form the foundation for the following study and inspire future exploration of supply chain frameworks and theoretical models.

### 3.1.2 *Questionnaire survey*

After achieving the first objective, the research will assess the 3D concrete printing and supply chain management challenges. A questionnaire survey, widely used to study the benefits, challenges, and impacts (Wu *et al.* 2018, Aghimien *et al.* 2020), is selected for effective data collection from academic and industry experts (Liu and Lin 2021). Data from the survey will be used to define key industry issues and propose solutions to decrease challenges.

Based on systematic review findings, the questionnaire includes questions on 3D printing implementation challenges, supply chain management, and their integration (Ma *et al.* 2024). A seven-point Likert scale is used to indicate the various opinions, which is a proven method for assessing significance and correlations (Tanujaya *et al.* 2022). This method gives the essential rating to discuss identified factors quantitatively (Tanujaya *et al.* 2022). Distributing high-quality questionnaires will contribute to a more reliable data result considering the target number of responses. So, a pilot study is conducted beforehand to improve the questionnaire and help to reduce research biases. Survey responses will be analyzed using the statistical method, including ranking, descriptive, and cluster analysis using SPSS. As Wuni and Shen (2020) state, the rank-based test is an effective statistical method to examine the differences in survey responses. With a target of 100 responses, the survey will recognize critical challenges in practical 3D concrete printing projects and clarify supply chain management concerns in a quantitative way.

### 3.1.3 *Semi-structured interview*

Incorporating experts' opinions through semi-structured interviews enhances the quality of the data collection. The interview will be designed based on the findings of the questionnaire survey, aiming to gather opinions from 30 experts, providing a flexible framework for obtaining rich insight supported by (Liu and Lin 2021). Allowing open-ended responses encourages participants to give their opinions on resolving issues and propose solutions to improve management efficiency.

The semi-structured interview framework aims to capture expert insights on supply chain challenges, decision-making criteria, and the feasibility of integrating decision support in 3D concrete printing. Questions are organized around predefined themes—cost efficiency, procurement, and risk management—while allowing flexibility for emerging topics. This ensures consistent yet adaptive data collection. Interview data will be analyzed using MCDM methods, specifically TOPSIS and WASPAS (Shojaei and Bolvardizadeh 2020), to rank supply chain factors by importance and performance. This approach transforms qualitative input into an actionable decision-making framework aligned with industry needs.

### 3.1.4 *Validation of research outcome*

This study will adopt a focus group to validate the effectiveness and applicability of the proposed decision support system. The focus group will consist of industry experts, such as supply chain managers from 3D concrete printing companies, who will evaluate the framework's practicality, usability, and alignment with real-world challenges in supply chain management (Shojaei and Bolvardizadeh 2020). Participants will provide critical feedback on the decision-making criteria, the system's adaptability to different operational contexts, and its potential impacts on efficiency and cost-effectiveness. The results will be used to refine the framework, ensuring its relevance and enhancing its implementation potential in the construction industry.

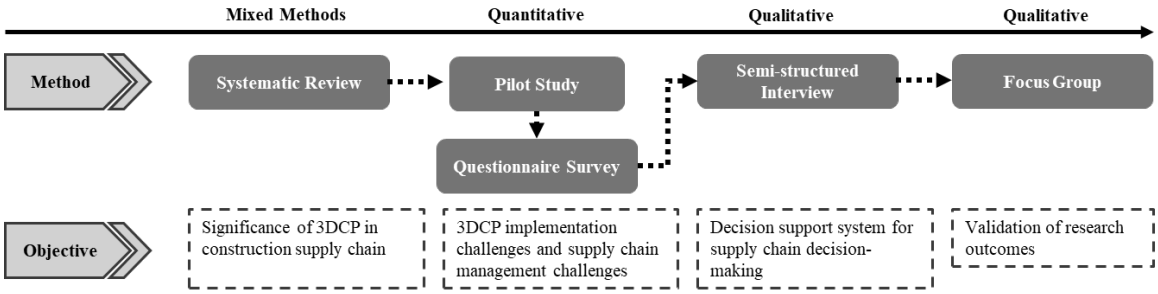


Figure 2. Research design.

The proposed research design is illustrated in Figure 2, with the systematic review and pilot study already completed. To mitigate the subjectivity and enhance the credibility of findings, triangulation will be employed through the integration of survey data, interviews, and focus group discussions. Participants are purposively selected to ensure diversity across roles, expertise, and organizational contexts. Although data collection is conducted in defined phases without iterative sampling, diversity in participant selection will be prioritized to enhance coverage. Member checking will be implemented to ensure that participants' opinions are accurately represented. Transparent procedures and adherence to established analytical frameworks further supported the reliability and representativeness of the results.

## 4 CONCLUSIONS

This study, conducted as part of a PhD project on 3D concrete printing supply chain management, establishes a structured methodology for developing a reliable decision support system. By aligning the research with its broader objectives, it demonstrates the suitability of questionnaire surveys and interviews for data collection and the rigour of multi-criteria decision-making methods for analysis. The four-stage process, systematic literature review, quantitative survey, semi-structured interviews, and a validating focus group, ensures both theoretical grounding and empirical robustness. Drawing on diverse professional perspectives and integrating quantitative and qualitative insights, the study enhances generalizability and provides a comprehensive understanding of supply chain challenges. Ultimately, this research strengthens the overall design and confirms the feasibility of producing a practical and impactful decision support framework to improve the efficiency and adoption of 3D concrete printing in construction.

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