Assessment of Cause-Effect of Design Defects in the Implementation Phase of Construction Projects

Phong Thanh Nguyen1,2\*, Linh Vu Ba Pham3,4, Thu Anh Nguyen3,4, Quan Khac Nguyen1,2, Phuong Thanh Phan1,2, and Hang Thi Thu Le5

1 Professional Knowledge & Project Management Research Team (K2P), Ho Chi Minh City Open University, Vietnam

2 Department of Project Management, Faculty of Civil Engineering, Ho Chi Minh City Open University, Vietnam*.*

3 Department of Construction Engineering and Management, Faculty of Civil Engineering,

Ho Chi Minh City University of Technology (HCMUT), 268 Ly Thuong Kiet, District 10, Ho Chi Minh City, Vietnam.

4 Vietnam National University Ho Chi Minh City, Linh Trung Ward, Thu Duc District, Ho Chi Minh City, Vietnam.

5 Department of Construction Management, University of Architecture Ho Chi Minh City, Vietnam

phong.nt@ou.edu.vn

**Abstract.** Design-related risks negatively affect construction project performance, in which, design defects (DD) are considered as one of the most important risks. Previous studies provide a diverse list of important factors related to DDs. However, very few of these studies have examined the interactions between factors in a cause-effect relationship. Identifying individual factors based on their importance can make it difficult to propose mitigation or prevention solutions. This study provides the important factors related to DDs based on their interactions by combining the rules of systems thinking for iterative cause-effect diagrams (CLD) and Decision-Making Trial and Evaluation Laboratory (DEMATEL). The research results showed that ‘Poor design consultancy’, ‘lack of checking and approval during the design process’, ‘lack or error of data before design’, and ‘careless, irresponsibility’ are the main causes of DDs. At the same time, DDs greatly influence project efficiency, which is reflected in factors such as ‘rework during construction’, ‘slow completion of the project’, ‘cost overrun’, and ‘rework of design documents’.

**Keywords:** Design Defects (DDs), Project Management, Design Management, Design Risk, Decision-Making Trial and Evaluation Laboratory (DEMATEL).

1. Introduction

The construction investment sequence goes through several stages, with the participation of many parties, contributing to the project the knowledge, skills, tools, and techniques to help the project operation. In particular, the project implementation phase always contains many potential risks and directly affects project productivity and efficiencies such as scope, schedule, cost, and quality [1-4]. The project implementation phase can be divided into two main parts including design and construction. The design phase has the most influence on the end performance of the project product but accounts for less cost than the later stages, especially the construction phase. Although the cost is relatively low, the amount of work performed during the design phase greatly affects the total project cost. Therefore, the causes and effects of defects in design documents, if not detected and resolved early, can lead to construction cost overruns, delays, complaints, and disputes, leading to project failures. This paper presents the main causes and effects of design document defects affecting project performance by exploring their interactions and proposing solutions to improve the quality of design documents, improve project efficiency, and bring practical benefits to project stakeholders.

1. Research Background

Design Defects (DD) are considered errors or omissions in the design documentation that negatively impact project performance [5-7]. Poor quality design documents are the cause of rework in construction, change orders, and conflicts between project stakeholders [8-10]. Project delays and costs are the most important effects of these issues [11]. The causes and effects of DD are increasingly diverse. For example, Minato [12] suggested that lack of cost and lack of time are the main factors causing DD. Slater and Radford [13] identified a lack of coordination among design disciplines and work overload as the causes of poor design documents. Based on a literature review of previous studies and interviews with construction experts, a summary list of cause-and-effect factors of DD is shown in tables below:

**Table 1.** List of causative factors for DD

|  |  |  |
| --- | --- | --- |
| Code | Causes of design firms’ managers | |
| A1 | Lack of design process | |
| A2 | Accept low design fees |
| A3 | Assign work to inexperienced employees | |
| A4 | Lack of coordination between the parties | |
| A5 | Insufficient funds to create quality documentation | |
| A6 | Lack of time to evaluate buildability | |
| A7 | Not enough time to plan | |
| A8 | Poor design consultancy | |
| A9 | Lack or error of data before the design | |
| A10 | Lack of checking and approval during the design process | |
| A11 | The design of the D&B general contractor is subject to many constraints in the project | |
| A12 | Too much work for the design manager | |
| A13 | Lack of training and coaching for design staff | |
| A14 | Lack of understanding of project requirements | |
| A15 | Lack of personnel in charge of design coordination and information provision | |
| A16 | Lack of qualifications and experience of designers | |
| A17 | Changing staff during the design process | |
| A18 | Low salary standards of design staff | |
| A19 | Inefficient design team organization | |
| A20 | Reusing instructions and details from a previous project | |
| Code | Causes about design firms’ staff | |
| B1 | Disagreements or conflicts between designers | |
| B2 | Inaccurate price survey of materials and equipment | |
| B3 | Heavy workload for designers | |
| B4 | Careless, irresponsibility | |
| B5 | Lack of knowledge about construction techniques and materials | |
| B6 | Designers do many things at the same time | |
| B7 | Error in calculation | |
| B8 | Lack of motivation | |
| B9 | Missing or incorrect information from other designers | |
| B10 | Missing 3D modeling and soft collision detection | |
| B11 | Lack of awareness about changes in standards and regulations | |
| B12 | Lack of coordination among design disciplines | |
| B13 | The designer's spirit is tense, uncomfortable, and lack of concentration | |
| B14 | Excessive compliance with software tools | |
| Code | Causes about investor | |
| C1 | Error in construction survey results | |
| C2 | Investors are late in approving the application | |
| C3 | Investors provide late input data | |
| C4 | Investors provide vague information and requirements | |
| C5 | The Investor does not agree on the main source of equipment or materials used | |
| C6 | The investor changes the design at no extra charge | |
| C7 | Build before finalizing the design | |
| C8 | Investor/Project Manager lacks planning and checking design documents | |
| C9 | The investor/project manager lacks experience in managing the design implementation process | |
| C10 | Slow communication between parties | |
| C11 | Delay in resolving conflicts between project participants | |
| C12 | The project is too complicated | |
| C13 | Solve the problem of lack of flexibility | |
| C14 | Poor-quality survey consulting | |
| C15 | Lack of representative for coordinating investor | |
| C16 | Lack of leadership from investors | |
| C17 | Investors have unrealistic requirements in terms of design time and costs | |

**Table 2.** List of factors affected by DD

|  |  |  |
| --- | --- | --- |
| Code | Effects about investor | |
| D1 | Complaints and disputes | |
| D2 | The late release of design documents |
| D3 | Slow completion of the project | |
| D4 | Error in the estimate | |
| D5 | Cost overrun | |
| D6 | Frequent changes in schedule | |
| D7 | The conflict between the parties | |
| D8 | Change design | |
| Code | Effects of design firms | |
| E1 | Decreasing the design company's reputation | |
| E2 | Difficulty in retaining qualified employees | |
| E3 | Rework of design documents | |
| E4 | Spending a lot of time checking the technical documents according to the investor's request | |
| E5 | Conflict of design disciplines | |
| E6 | Design profit reduction | |
| Code | Effects of contractors | |
| F1 | Pressure on main contractors and subcontractors | |
| F2 | Rework during construction | |
| F3 | The contractor abandoned the bidding package | |
| F4 | Errors in contractor contract documents | |
| F5 | Accident | |
| F6 | More work to ensure quality requirements | |
| F7 | Incomplete design at the tender | |
| F8 | Excessive design | |
| F9 | Frequently asking for more information | |
| F10 | Frequently a change of offer | |

1. Research Methodology

The research process is shown in Figure 1 as follows:



**Fig 1**. Research process

A questionnaire survey, causal loop diagram(CLD)and Dematel methods were used in this study.The questionnaire was sent to construction experts in the form of a google form via email through three stages: (i) Phase 1: surveying the importance of cause-effect factors related to DD for 32 construction experts with more than 7 years of experience; (ii) Phase 2: Interview construction experts with more than 10 years of experience to determine the causal loop diagram and the relationship matrix between the factors; and (iii) Phase 3: surveying the influence of factors together in the system on 55 individuals engaged in construction activities in Ho Chi Minh City.

The next section summarizes the steps to implement the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method [14-18]:

* Step 1: Build a influence-relationship matrix
* Step 2: Develop a normalized influence-relationship matrix
* Step 3: Calculate the composite influence-relationship matrix
* Step 4: Determine the terms of row sum *Hi*, column sum *Cj*, sum (*Hi* + *Cj*), value (*Hi-Cj*) of the composite matrix
* Step 5: Sum (*Hi* + *Cj*) illustrates how important the variable *i* is in the whole system.
* Step 6: The value of (*Hi* - *Cj*) shows the net effect that variable *i* has in the system

1. Research Results

Based on the application of the above research methods, the calculation results are summarized in the following table:

**Table 3.** Ranking comparison between RII and DEMATEL

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Code** | **Factor** | **RII** | **DEMA TEL** | **Ranking** | **RII** | **DEMA TEL** | **Ranking** |
| **Ranking in group** | | | **Ranking in system** | | |
| **I** | **Causes of design firms’ managers** | | | | | |  |
| A1 | Lack of design process | 5 | 4 | rank up | 6 | 12 | rank down |
| A3 | Assign work to inexperienced employees | 3 | 5 | rank down | 3 | 13 | rank down |
| A4 | Lack of coordination between the parties | 4 | 11 | rank down | 4 | 33 | rank down |
| A8 | Poor design consultancy | 1 | 1 | unchanged | 1 | 1 | unchanged |
| A9 | Lack or error of data before the design | 2 | 3 | rank down | 2 | 8 | rank down |
| A10 | lack of checking and approval during the design process | 8 | 2 | rank up | 21 | 7 | rank up |
| A14 | Lack of understanding of project requirements | 7 | 8 | rank down | 15 | 27 | rank down |
| A16 | Lack of qualifications and experience of designers | 9 | 6 | rank up | 22 | 18 | rank up |
| A17 | Changing staff during the design process | 6 | 10 | rank down | 9 | 31 | rank down |
| A19 | Inefficient design team organization | 10 | 7 | rank up | 23 | 23 | unchanged |
| A20 | Reusing instructions and details from a previous project | 11 | 9 | rank up | 33 | 30 | rank up |
| **II** | **Causes of design firms’ staff** |  |  |  |  |  |  |
| B4 | Careless, irresponsibility | 3 | 1 | rank up | 24 | 9 | rank up |
| B5 | Lack of knowledge about construction techniques and materials | 5 | 3 | rank up | 34 | 26 | rank up |
| B7 | Error in calculation | 4 | 2 | rank up | 31 | 24 | rank up |
| B11 | Lack of awareness about changes in standards and regulations | 2 | 4 | rank down | 19 | 28 | rank down |
| B12 | Lack of coordination among design disciplines | 1 | 5 | rank down | 11 | 29 | rank down |
| **III** | **Causes of investor** |  |  |  |  |  |  |
| C1 | Error in construction survey results | 2 | 2 | unchanged | 16 | 15 | rank up |
| C4 | Investors provide vague information and requirements | 3 | 3 | unchanged | 17 | 20 | rank down |
| C7 | Build before finalizing the design | 1 | 4 | rank down | 7 | 25 | rank down |
| C14 | Poor-quality survey consulting | 5 | 5 | unchanged | 32 | 34 | rank down |
| C17 | Investors have unrealistic requirements in terms of design time and costs | 4 | 1 | rank up | 25 | 14 | rank up |
| **IV** | **Effects of investor** |  |  |  |  |  |  |
| D1 | Complaints and disputes | 5 | 5 | unchanged | 18 | 19 | rank down |
| D2 | The late release of design documents | 6 | 6 | unchanged | 26 | 22 | rank up |
| D3 | Slow completion of the project | 7 | 1 | rank up | 27 | 3 | rank up |
| D4 | Error in the estimate | 3 | 7 | rank down | 12 | 32 | rank down |
| D5 | Cost overrun | 1 | 2 | rank down | 5 | 4 | rank up |
| D7 | The conflict between the parties | 2 | 4 | rank down | 8 | 11 | rank down |
| D8 | Change design | 4 | 3 | rank up | 13 | 6 | rank up |
| **V** | **Effects of design firm** |  |  |  |  |  |  |
| E1 | Decreasing the design company's reputation | 1 | 2 | rank down | 14 | 16 | rank down |
| E3 | Rework of design documents | 2 | 1 | rank up | 28 | 5 | rank up |
| E5 | Conflict of design disciplines | 3 | 3 | unchanged | 29 | 17 | rank up |
| E6 | Design profit reduction | 4 | 4 | unchanged | 30 | 21 | rank up |
| **VI** | **Effects of contractor** |  |  |  |  |  |  |
| F2 | Rework during construction | 2 | 1 | rank up | 20 | 2 | rank up |
| F10 | Frequently a change of offer | 1 | 2 | rank down | 10 | 10 | unchanged |

The research results in table 3 showed that there are many differences in factor ranking between RII and DEMATEL methods. Except for poor design consultancy which is considered as the most important factor in both methods, lack of checking and approval during the design process and carelessness, irresponsibility are the two main reasons that cause DD according to DEMATEL but are considered less important according to RII. At the same time, factors affecting stakeholders by DD such as rework during construction, slow completion of the project, rework of design documents, and change design are ranked in the first 10 categories according to DEMATEL but ranked low in RII. The main difference is that in addition to considering the importance of the factors, DEMATEL also considers the level of impact between the factors in the system. Thus, by preventing the important cause-effects of DDs and mitigating their interactions with other factors, the risks posed by DDs can be prevented.

1. Conclusion

Design defects are considered as one of the main causes of delay, and cost overruns, negatively affecting project efficiency if we are not detected early and properly resolved. This study evaluates the important factors related to design defects and their cause-and-effect relationships in the same system. The research results showed that ‘Poor design consultancy’, ‘lack of checking and approval during the design process’, ‘lack or error of data before design’, and ‘careless, irresponsibility’ are the main causes of DDs. At the same time, DDs greatly influence project efficiency, which is reflected in factors such as ‘rework during construction’, ‘slow completion of the project’, ‘cost overrun’, and ‘rework of design documents’. Therefore, improving the quality of design consultants is the most effective solution For design consultants, it is necessary to develop an overall quality management system to avoid the possibility of errors and omissions in the design documents. Develop a process to improve design quality and train and guide employees from low-level to senior management. In addition, applying Bim to design products also contributes to increasing the quality of records, reducing errors and possible conflicts. This helps improve the reputation and reputation of the consulting unit, increase competitive advantage and profits.

**Acknowledgment**

The authors would like to thank the Professional Knowledge & Project Management Research Team (K2P), Ho Chi Minh City Open University, Vietnam for supporting this research.

References

1. S. Iqbal, R. M. Choudhry, K. Holschemacher, A. Ali, and J. Tamošaitienė, "Risk management in construction projects," *Technological and economic development of economy,* vol. 21, no. 1, pp. 65-78, 2015.
2. D.-L. Luong, D.-H. Tran, and P. T. Nguyen, "Optimizing multi-mode time-cost-quality trade-off of construction project using opposition multiple objective difference evolution," *International Journal of Construction Management,* vol. 21, no. 3, pp. 271-283, 2021.
3. P. Q. Tran, T. T. Y. Huynh, T. T. Dang, N. T. Q. Tran, and P. T. Nguyen, "Evaluating risks in Ho Chi Minh city urban railway project using analytic network process," in *AIP Conference Proceedings*, 2022, vol. 2453, no. 1: AIP Publishing LLC, p. 020071.
4. N. B. Siraj and A. R. Fayek, "Risk identification and common risks in construction: Literature review and content analysis," *J. Constr. Eng. Manage.-ASCE,* vol. 145, no. 9, p. 03119004, 2019.
5. S. Assaf, M. A. Hassanain, and A. Abdallah, "Review and assessment of the causes of deficiencies in design documents for large construction projects," *International Journal of Building Pathology and Adaptation,* vol. 36, no. 3, pp. 300-317, 2018.
6. A. Abdallah, S. Assaf, and M. A. Hassanain, "Assessment of the consequences of deficiencies in design documents in Saudi Arabia," *Architectural engineering and design management,* vol. 15, no. 4, pp. 282-296, 2019.
7. J. T. O’Connor and H. J. Koo, "Analyzing the quality problems and defects of design deliverables on building projects," *Journal of Architectural Engineering,* vol. 26, no. 4, p. 04020034, 2020.
8. J. Woo and J. T. O’Connor, "Causal factors for engineering design defects and their impacts," *Practice Periodical on Structural Design and Construction,* vol. 26, no. 2, p. 04020071, 2021.
9. N. Jaffar, A. A. Tharim, and M. Shuib, "Factors of conflict in construction industry: a literature review," *Procedia Engineering,* vol. 20, pp. 193-202, 2011.
10. A. S. Alnuaimi, R. A. Taha, M. Al Mohsin, and A. S. Al-Harthi, "Causes, effects, benefits, and remedies of change orders on public construction projects in Oman," *J. Constr. Eng. Manage.-ASCE,* vol. 136, no. 5, pp. 615-622, 2010.
11. B. Mpofu, E. G. Ochieng, C. Moobela, and A. Pretorius, "Profiling causative factors leading to construction project delays in the United Arab Emirates," *Engineering, Construction and Architectural Management,* 2017.
12. T. Minato, "Design documents quality in the Japanese construction industry: factors influencing and impacts on construction process," *Int. J. Proj. Manag.,* vol. 21, no. 7, pp. 537-546, 2003.
13. R. Slater and A. Radford, "Perceptions in the Australian building industry of deficiencies in architects' design documentation and the effects on project procurement," *Constr. Econ. Build.,* vol. 8, no. 1, pp. 23-33, 2008.
14. J. J. Liou, Y.-C. Chuang, E. K. Zavadskas, and G.-H. Tzeng, "Data-driven hybrid multiple attribute decision-making model for green supplier evaluation and performance improvement," *Journal of Cleaner Production,* vol. 241, p. 118321, 2019.
15. A. Kumar, M. A. Kaviani, A. Hafezalkotob, and E. K. Zavadskas, "Evaluating innovation capabilities of real estate firms: a combined fuzzy Delphi and DEMATEL approach," *Int. J. Strateg. Prop. Manag.,* vol. 21, no. 4, pp. 401-416, 2017.
16. T. T.-M. Huynh, A.-D. Pham, and L. Le-Hoai, "Building a strategic performance management model for enterprises investing to coastal urban projects toward sustainability," *Int. J. Strateg. Prop. Manag.,* vol. 25, no. 2, pp. 127-145, 2021.
17. S.-L. Si, X.-Y. You, H.-C. Liu, and P. Zhang, "DEMATEL technique: A systematic review of the state-of-the-art literature on methodologies and applications," *Mathematical Problems in Engineering,* vol. 2018, pp. 1-33, 2018.
18. A. Kumar, M. A. Kaviani, E. Bottani, M. K. Dash, and E. K. Zavadskas, "Investigating the role of social media in polio prevention in India: a Delphi-DEMATEL approach," *Kybernetes,* 2018.