



Investigation and Analysis of the Rework Leading Indicators in Construction Projects: State-of-the-Art Review

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Abstract: During the design and construction phases, many large-scale construction projects suffer from the issuance of rework that ultimately lead to substantial cost overruns and major schedule delays. It is estimated that more than half of the construction projects encounter significant rework and subsequent cost overruns and schedule delays. Scholars and practitioners worldwide are assessing the impact of these rework and the critical causes behind them, primarily focusing on identifying the entity-based rework indicators, as it is crucial to identify the key project, human, and organizational factors that lead to the rework. This study investigated, identified, and prioritized the human, organization, and project-based indicators of rework. Numerous research documents were reviewed to identify the leading rework indicators and prioritize them, based on their frequency of occurrence in the literature. Poor design, a vague scope definition, and site location issues are the project-based indicators most frequently found in literature; ineffective coordination and communication are the organization-based rework indicators most often found in literature; and lack of knowledge, skills, and experience are the most critical and frequently referenced indicators for human-based rework. The findings of this study will help practitioners identify the causes of rework at the right time in order to allocate resources properly for mitigating the number and cost of rework.

1 INTRODUCTION

Rework (change orders) are inevitable in all types of construction projects. They play an important role in a project's success or failure, as they impact the cost of a project, create scheduling delays, and decrease productivity. Rework and their consequences vary significantly from project to project because of the uniqueness of estimated cost; estimated schedule; and availability of resources for planning, such as time, money, and manpower.

Reworks are usually issued to modify the design during the design and construction phases, but can be issued for various reasons by the stakeholders. They have a significant potential for creating serious challenges for owners, designers, and contractor stakeholders, and may also cause conflicts among them (Kermanshachi and Safapour 2019; Kermanshachi et al. 2019). Hence, it is critical to identify the causes of change orders and quantify their impacts on the execution of construction projects (Wu et. al 2004, Sunday 2010, Desai 2015; Safapour and Kermanshachi 2019).

Rework has a negative impact on construction performance and productivity (Habibi et al. 2018a and 2018b; Safapour et al. 2018). According to Baxendale and Schofield (1986), rework can be defined as any change that veers from the agreed upon and signed contract. Ssegawa et al. (2002) stated that changes of designs or in the construction process itself must be expected because of the complexity of construction projects, and change orders in both the design and construction phases are unavoidable. Therefore, the construction industry is subject to poor cost management and schedule performance due to design modifications (Ssegawa et al. 2002).

Several studies have been conducted to investigate the root causes of change orders and their unfavorable consequences on construction projects (Kermanshachi et al. 2017; Safapour and Kermanshachi 2019; Kermanshachi and Rouhanizadeh 2019). Many researchers (Moselhi et al., 2005; and Kean et al., 2010; Safapour et al. 2018) categorize the root causes of change orders by the source: those that are owner-derived, consultant-related, and contractor-related. Owners commonly modify the scope of projects, and consultants and contractors usually employ rework to correct or modify the design of projects. Some researchers have stated that owner-initiated changes in plans and scope are the main source of change orders, and design errors and modifications are the secondary sources (Al-Dubaisi et al., 2000, and Al-Hams, 2010).

Love et al., 2012a and 2012b, concluded that project systems have inherent and latent problems, such as organizational issues (e.g., lack of quality management), project issues (e.g., definition of scope), and individual issues (e.g., work experience of staff). The authors also found that these can set the stage for designers to make mistakes. Love et al. (2012a) labeled the established taxonomy as people, organizations, and project systems. These nomenclatures highlight the process that enables the mapping of dependencies and interfaces that affects error prevention. Furthermore, the authors explained that considering mistake prevention as a continuous process highlights the belief that the ability to learn from mistakes is a collective capacity that can provide useful to aiding in the reduction of organizational, project, and people-related mistakes.

Throughout the recent twenty years, numerous researchers have attempted to identify the critical causes of rework. Despite the investigation of a number of rework indicators, still there is no definitive list of project, organization, or human based rework indicators in the literature. Thus, the objective of this study is to conduct a comprehensive review of related papers written on rework, to provide a list of human, project, and organization rework indicators. For this purpose, this study first critically examined the research efforts pertaining to rework indicators that belong to the project, organization, and human categories. Then, the effectiveness assessment methods that were used in the reviewed journal articles to collect the rework indicators were studied. Next, the most frequently mentioned human, organization, and project-based rework indicators were investigated and listed. In summary, the ability to predict potential causes of rework early in the design and construction phases offers significant benefits to industry practitioners and project managers.

2 RESEARCH METHODOLOGY

To fulfil the objectives of this study, a five-step research framework was developed, as presented in Figure 1. More than 100 peer-reviewed journal articles, conference papers, dissertations, and research reports that focused on rework variables belonging to organization, project, and human categories were reviewed. Among them, 57 journal articles that were published after 2000 were deemed to be the most relative, and were reviewed carefully in order to collect the essential data, including the name of journal, the year of the study, country of origin, and list of rework indicators. The data analyses were conducted, and the results were interpreted and discussed.

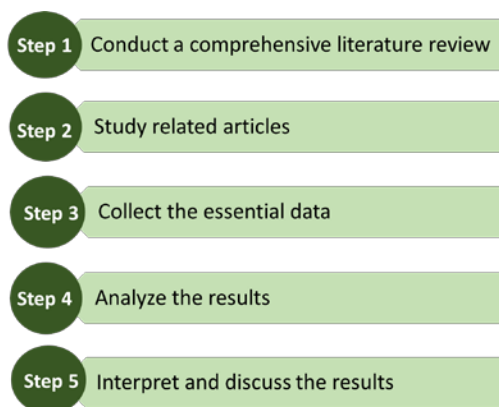


Figure 1. Research Framework.

2.1 Journal Name

Project, organization, and human rework indicators found in construction have been published in eight different journals around the world, as presented in Table 1. This table specifies the distribution of the journal articles by the name of journal. As indicated in Table 1, the largest number (15) and percentage (26.30%) of the reviewed articles were published by the Journal of Construction Engineering and Management. The Journal of Management in Engineering published the second highest number of articles related to rework indicators (7), which amounted to 17.95% of all of the articles published on the subject.

Table 1. Frequency and Percentage of Reviewed Articles for Rework Indicators

Journal Title	Frequency	Percentage (%)
Journal of Construction Engineering and Management	15	26.30%
Journal of Management in Engineering	7	12.28%
International Journal of Project Management	4	7.00%
International Journal of Sustainable Construction Engineering and Technology	4	7.00%
IEEE Transactions on Engineering Management	4	7.00%
Construction Management and Economics	2	3.50%
Journal of Infrastructure System	2	3.50%
Journal of Performance of Constructed Facilities	2	3.50%
Other Journals*	17	29.92%

* Other journals are those that published one article, including the Engineering, Construction, and Architectural Management Journal.

2.2 Year of Study

As indicated in Figure 2, the journal articles published after 2000 were grouped and analyzed. This figure also shows that after 2011, there was a sudden increase in the number of journal articles written about construction rework indicators belonging to project, organization, and human categories. With 28 journal articles published between 2012 and 2017, this time period was recorded as the highest frequency of rework-indicators-related studies among all two-year targeted intervals. The last group consisted of articles published in 2018, as the year 2019 has just begun.

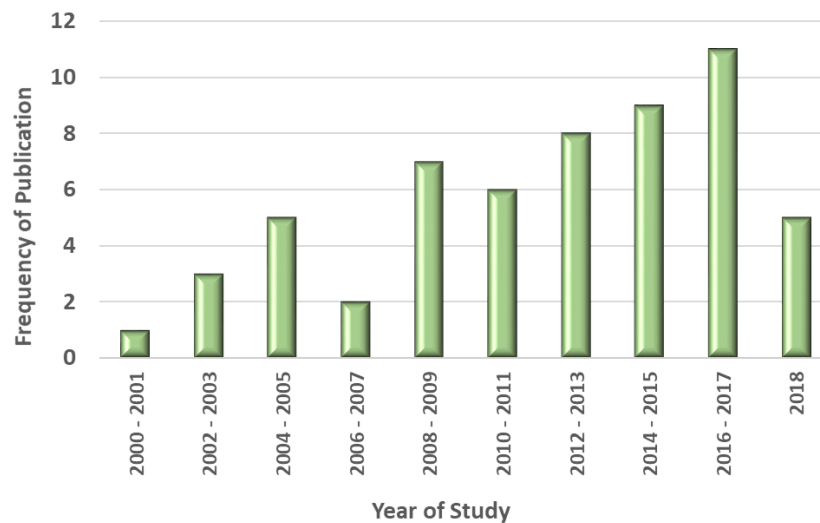


Figure 2. Distribution of Journal Articles According to Year of Study

2.2 Country of Origin

Figure 3 illustrates the distribution of papers, based on percentage, according to their country of origin. Researchers from all over the world have identified and studied the rework indicators belonging to the three stated main categories. As shown in Figure 3, rework issues have been a challenging phenomenon in developing countries on the continents of Asia and Africa. This map shows that Asia (33%) and Australia (25%) were recorded as publishing more papers than any other continent.

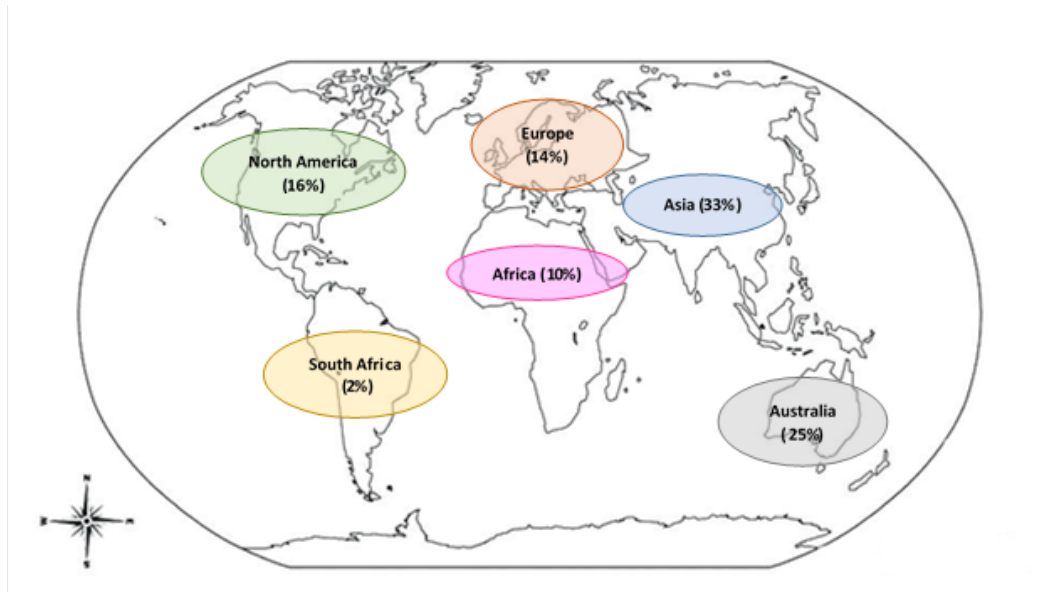


Figure 3. Distribution of Rework Papers Based on the Country of Origin

3 RESEARCH RESULTS

3.1 Project-Based Rework Indicators

The project-based rework indicators were identified and analyzed. Table 2 depicts the frequency and ranking of the top frequent project-based rework indicators, and indicates that the eight critical and most frequent project-based rework indicators were identified through existing literature. These identified indicators were inappropriate/poor design, unclear scope definition, site location issues, material issues, supervision-related issues, financial issues, unclear task specifications, and quality issues. Kermanshachi et al. (2017) concluded that unclear or vague scope is one of the major reasons which leads to occurrence of rework during the construction phase resulting in significant raise of project cost and timeframe. Research studies found out that implementation of the organized training sessions and workshops for the participants improves the quality of the developed scope and results in accurate estimated cost and time for EPC phases of the project (Kermanshachi et al. 2016 and 2018).

Table 2 shows that the indicator “inappropriate/poor design” was recorded as the most frequently observed rework indicator belonging to project category. Reason and Hobbs (2003) defined poor design as a deviation from an intended course of action and path of actions planned toward a favorable target. Similarly, Love et al. (2009) and Habibi et al. (2019) explained that a poor construction design commonly arises and causes considerable schedule delays.

Table 2 clearly shows that the indicator “unclear scope definition” occurred with the second highest frequency (28) among those belonging to the project category. Fagheha and Aibinu (2013) described project scope definition as “*the process whereby a project is defined and prepared for execution.*” Gunhan and Arditi (2007) believed that if the scope of a project is thoroughly defined, the design contingency is absorbed into the baseline budget for a particular cost factor. A clear definition of the scope leads to early

clarification of the project's scope and goals, and reduces the late design changes/modifications that are due to changing the project scope (Safapour and Kermanshachi 2019). An unclear scope definition usually causes some design changes/modifications at the start of construction, and construction may begin with an undefined disagreement over the work space.

As presented in Table 2, the project-based rework indicator "site location issues" received the third highest indicator. Wu et al. (2004) explained that the soil strength and foundation location may differ from expectations, leading to change orders. Underground pipes are often not located where the reports indicated that they would be, which creates problems that necessitate rework. Material issues was the other critical project-based rework indicator, as shown in Table 2. Wu et al. (2004) stated that when certain material items required by the design are either inadequate or out of stock, changes in the material(s) used and/or method(s) employed occur. Similarly, Sun and Meng (2009) stated that the unavailability of material during the execution of the project leads to a replacement, and might cause change orders to be issued.

Table 2. Frequency and Ranking of Project-Based Rework Indicators

Indicator	Frequency	Ranking
Inappropriate/Poor design	38	1
Unclear scope definition	28	2
Site location issues	19	3
Material issues	14	4
Supervision related issues	12	5
Financial issues	11	6
Unclear task specification	7	7
Quality issues	7	7

3.2 Organization-Based Rework Indicators

The other critical rework indicators, which were identified and analyzed through existing literature, belong to the organization category. The most frequent and important organization-based rework indicators are presented in Table 3. The most seven important and frequent indicators are: ineffective coordination, lack of resource management, ineffective communication, lack of training, lack of design control and regular audit, lack of documentation control, and poor management.

Table 3 illustrates that inappropriate coordination received the highest frequency (37) among the organization-based rework indicators. Many researchers (Si et al. 2008, Gkeredakis 2010, Noor 2010, Lotfi and Ghaderi 2013, Alaloul et al. 2016; Safapour et al. 2017) believed that poor coordination between stakeholders might lead to rework that are necessary for executing and delivering the project. Khanzodeh et al. (2008) described coordination as "*managing dependencies between activities.*" Hwang and Yang (2014) explained that ineffective coordination leads to deviations from the necessary requirements; thus, rework occur to minimize the schedule delays. For instance, inappropriate coordination among design staff might lead to discrepancies in the design phase, consequently causing errors to occur in the construction phase. Effective coordination among consultant stakeholders minimizes the number and cost of rework during the construction phase.

As presented in Table 3, ineffective communication was recorded as one of the most frequent rework indicators belonging to the organization category. Malisiovas (2014) described the definition of communication as "*friendship or collaborations in projects, mutual organizational work, and others.*" Likewise, Chinowsky et al. (2010) defines communication as "*a direct relation within the success of a project and the appropriate amount of communication and knowledge-sharing while completing a set of tasks.*" Senescu et al. 2013 defines communication as the interaction that emerges while there is an interaction among project members. Many studies (Cheng et al. 2001, Affare 2012, Forcada et al. 2017, Kamalirad et al. 2017, Kamalirad and Kermanshachi, 2018, Lee and Kim 2018; Safapour et al. 2019) were conducted and revealed that communication is one of the most important factors of project success because of the number of parties involved and the number of issues that need to be addressed. Ineffective communication

prevents timely sharing of information and knowledge among parties, frequently resulting in errors that result in rework in the construction phase.

Poor management was recorded as one of the critical organization-based rework indicators in literature. Xie et al. (2010) explained that an experienced project management team can effectively manage projects. As the project management team is commonly responsible for applying knowledge, skills, tools, and techniques to deliver the project's objectives, insufficient experience and poor management results in improper management of the staff and eventually in rework.

Table 3. Frequency and Ranking of Organization-Based Rework Indicators

Indicator	Frequency	Ranking
Ineffective coordination	37	1
Lack of resource management	20	2
Ineffective communication	18	3
Lack of training	18	4
Lack of design control and audit	16	5
Lack of documentation control	14	6
Poor management	12	7

3.3 Human-Based Rework Indicators

The other critical rework indicators that were identified and analyzed through the literature belonged to the human category. The most frequent and important human-based rework indicators are presented in Table 4. The five most critical and frequent indicators were: lack of staff experience, lack of skill, lack of knowledge, lack of safety commitment, and lack of motivation.

Table 4 indicates that if the staff has insufficient experience, the probability of rework increases. For instance, if the designers have inadequate knowledge, skill, and experience about the design of the construction project, the number of errors will increase, and there is a greater probability that the cost of rework due to design changes and modifications will also increase. In addition, Forcada et al. (2014 and 2017) explained that design and construction errors will be made when personnel suffer from a lack of knowledge, skill, and expertise.

As shown in Table 4, safety commitment is the other important human-based rework indicator in literature. Wanburg et al. (2013) believed that recordable injuries are directly correlated to the number of rework. Similarly, Love et al. (2018) explained that when staff lack a strong commitment to safety, they often engage in risky behavior by not doing what was planned. Injuries that are due to a lack of safety commitment exert pressure on other personnel to meet the schedule deadlines, and working under pressure often results in rework.

Table 4. Frequency and Ranking of Human-Based Rework Indicators

Indicator	Frequency	Ranking
Lack of experience	16	1
Lack of skill	15	2
Lack of knowledge	11	3
Lack of safety commitment	4	4
Lack of motivation	3	5

4 CONCLUSION

This study identified rework early indicators and categorized them according to organization, project, and people through existing literature. The results revealed that inappropriate/poor design, an unclear scope definition, site location issues, material issues, supervision-related issues, financial issues, vague task specifications, and quality issues were the most frequent project-based rework indicators. This study also demonstrates that the seven most frequent rework indicators belonging to the organization category are: ineffective coordination, lack of resource management, ineffective communication, lack of training, lack of design control and audit, lack of documentation control, and poor management. Finally, it was concluded that, based on the literature, the lack of experience, knowledge, skills, safety commitment, and motivation are the most crucial human-based rework indicators. It is anticipated that the outcomes of this study will assist project managers and practitioners in understanding the causes of rework so that the execution of their projects will require minimum design modifications and rework.

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