Analyzing causes for reworks in construction projects in China

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Published in:
Journal of Management in Engineering

DOI:
10.1061/(ASCE)ME.1943-5479.0000347

Causes of construction project rework in China[1]

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Abstract:

Although rework is a common phenomenon in the Chinese construction industry and significantly affects project success, the reasons of rework remain largely unknown and most construction companies are unable to manage the issue effectively. To investigate the causes of rework in construction projects, a total of 39 causes were first identified through a comprehensive literature review and semi-structured interviews with 13 experienced construction professionals in China. A questionnaire survey was further conducted to prioritize these causes, in which *unclear project process management*, *poor quality of construction technology* and *use of poor construction materials* rank the highest. Finally, a factor analysis revealed 11 major underlying dimensions of these causes, relating to design management, communication management, field management, project scope management, project process management, active rework, project plan changes, subcontractor management, contract management, owner capability and external environment. The contribution of this work lies in its examination of the underlying causes of rework perceived by construction professionals in the world’s largest developing country characterized by its unique economic and social systems. In particular, newly identifed causes of contract management, active rework and scope management help expand existing knowledge of the underlying causes of rework for the global construction community.

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Foundation item：Project No. CDJSK-12030005 supported by the Fundamental Research Funds for the Central Universities and Project No.12YJCZH255 supported by The Ministry of Educati on of Humanities and Social Sciences project.

Key words: rework, cause, construction projects, factor analysis, China

Introduction

Construction project rework means to redo the work that has already been done with the main purpose of satisfying the functional demand of the project. It is a significant problem for construction and engineering projects (Palaneeswaran et al., 2008; Hwang et al., 2009; Love et al., 2010, 2011), and significantly affects project success as it causes problems such as cost overrun and schedule delay. The cost of rework in major civil engineering projects ranges from 5 to 20% of contract value (Burati 1992; Barber et al., 2000). It is therefore very important to effectively reduce rework as much as possible.

The root causes of rework need to be identified before it can be effectively managed (Fayek et al., 2003; Hwang et al., 2009), and a number of these have already been identified (e.g. Josephson et al. 2002; Fayek et al. 2003; Palaneeswaran et al.2008; Hwang et al., 2009; Love et al. 2010; Mastenbroek, 2010) (see Table 6). These apply mainly in developed countries/regions however and little is known of rework causes in developing countries. This includes China (Tan, 2007), a country with the largest construction industry in the world, with an added value of 3,899.5 billion yuan (1 yuan= 0.16 U.S. dollars in July 2014) (McGraw-Hill，2011; National Bureau of Statistics of China, 2014).

Therefore, this study aimed to understand the causes of rework in the Chinese construction industry so that suitable measures for rework management can be devised. To achieve this, semi-structured interviews and a broad questionnaire survey approach were adopted. Based on the data collected from the questionnaire survey, a factor analysis is used to identify 11 underlying dimensions involved, comprising design management, communication management, field management, project scope management, project process management, active rework, project plan changes, subcontractor management, contract management, owner capability and external environment.

Table 6 Rework factors in other countries/ regions

Rework Cause	China	Sweden	Canada	UK	Netherlands	Hong Kong	Australia
	Current study	Josephson et al.（1998, 2002）	Fayek et al. (2003)	Hwang et al.(2009)	Mastenbroek（2010）	Palaneeswaran et al.（2008）	Love et al. (2002)
F1	Field management	√	√		√	√	√
F2	External environment				√		
F3	Contract management						
F4	Subcontractor management					√	
F5	design management	√		√		√	√
F6	Project communication		√		√		
F7	Plan changes	√			√		
F8	Active rework						
F9	owner capability	√		√		√	√
F10	Scope management						
F11	Process management		√				

Literature review

It is necessary to first clarify the definition of rework, as the way in which it is defined always leads to a different research method, which in turn leads to different research results (Love et al., 2010). Ashford (1992) defines rework as the redo and recover process of making the constructed subject satisfy the original construction goal. The Construction Industry Development Agency (1995), on the other hand, defines rework as the extra work caused by an inconsistency with the original demand of the project. Love (2002) states that rework is the process or event caused by deviations, faults, unqualified quality problems or quality accidents, while. Josephson et al. (2002) define rework as unnecessary output caused by mistakes undertaken during the construction process. According to Good Manufacture Practice (2010), rework refers to the production of a product that has not satisfied the quality standards of the regular procedures. As the definitions above demonstrate, rework is normally defined from a negative and passive perspective, although it can also be an active process of redoing some parts of a project to improve its function or its value despite already having satisfied the original expected function.

A variety of researchers and organizations worldwide has conducted research to identify the causes of rework for different types of projects. Burati et al. (1992) investigate the influential factors for nine industrial projects from the U.S. Construction Industry Institute (CII) database. They point to five major reasons for rework being design, construction, fabrication, transportation and operability. Using construction projects from the same CII database, Hwang et al.（2009） investigate the causes of rework in 359 construction projects and identify the most significant of these to be owner changes and design errors/omissions.

From 1999 to 2002 in Australia, Love et al. (1999), Love and Li (2000) and Love et al. (2002) carried out a series of research projects to ascertain the causes of construction project rework. These conclude that, for residential construction projects, rework is predominantly attributed to design errors and design changes, while for industrial construction projects, rework is mainly caused by construction changes and construction errors due to poor detailing and workmanship. Similar studies were later conducted with civil engineering projects (e.g. Love et al. 2004; Love et al., 2009; Love et al., 2010). For example, Love et al. (2010) use stepwise multiple regression analysis to determine the major variables involved in 115 Australian civil engineering projects. The results indicate the main rework causes to be the ineffective use of information technology, excessive owner involvement in the project, lack of clearly defined working procedures, changes made at the request of the owner and insufficient changes initiated by the contractor to improve quality.

In an investigation of seven Swedish building projects, Josephson and Hammarlund (1999) identify eight principal rework causes, including instability of the owner organization, owner project control, user involvement, time pressures, composition of the project organization, cost pressures, site organization support and motivation of people. Josephson et al.（2002）later carried out another study of Swedish building projects, finding the most significant causes of rework to be erroneous workmanship, unsuitable or faulty design, lack of coordination in design, late delivery of materials, mistakes in planning and faulty manufacturing. A year later in Canada, the Construction Owners Association of Alberta (COAA) (2003) used a Cause and Effect (CE) diagram (also known as a fishbone diagram) to explore all the potential or actual causes of rework, finding the main reasons for rework to be *consistency not ensured before issued for construction*, *lack of inspection* and *poor workmanship of prefabricated material*.

Previous research regarding rework in construction projects has mainly focused on major developed countries and regions (e.g. America, Australia, Canada and Sweden) and very few similar studies have been attempted in developing countries. Oyewobi et al. (2011) in Nigeria evaluate rework cost on an elemental basis; however the underlying reasons for rework relating to different elements of buildings need further investigation. Marujo (2009) adopt system dynamics to evaluate the impact of rework but the research results need to be further refined and developed. Yang and Zhou (2008) examine the rework problems of building projects in China through a concurrent engineering approach; however the causes for the rework remain unknown. Given the fast growth of the Chinese construction industry and its recurring rework problems, there is a need to identify the underlying causes involved. This will enable solutions for effectively managing reworks to be developed in the future.

Semi-structured interviews

To collect data relating to the uses of rework of construction projects in China, a thorough literature review was first carried out to identify a preliminary list of those involved. The studies reviewed not only relate to rework identification and management in construction projects (e.g. Love et al., 2004; Palaneeswaran et al. 2008; Hwang et al., 2009; Love et al., 2010), but also encompass project quality management (e.g. Cheng 2004; Ren and Zhang 2005), quality deviations (e.g. Burati et al., 1992; Hou et al., 2008), nonconformance（Abdul-Rahman 1995), defects (e.g. Hammarlund and Josephson, 1991; Josephson and Hammarlund, 1999; Meng, 2005;), quality failures (e.g. The Center For Housing Industrialization, 2007) and construction delays (e.g. Aibinu and Odeyinka, 2006; Lo et al., 2006), all of which helped to develop an in-depth understanding concerning (a) the likely causes of construction rework, and (b) how they influence project performance. This resulted in the identification of an initial list of 47 rework causes.

Semi-structured interviews were then conducted with 13 experts, consisting of one academic, two project owners, four on-site project managers, two quality supervisory engineers, one project designer, two supervisors from government，two site foreman and two construction monitors. The reason for the combination of experts from different backgrounds was to provide a balanced view of the research topic. All these experts have sufficient working experience in the industry and frequently deal with rework issues. They were requested to identify the rework causes according to their own experience. Each interview lasted approximately 30 minutes. The rework causes identified from the literature review were provided for their reference. In particular, they were requested to take into consideration the unique characteristics of construction projects in China. The number of interviews is regarded as appropriate, as data saturation was reached (no new causes emerged in the final stage of the interviews). Content analysis was then employed to identify the causes of rework from the interview transcripts. This is often used to determine the major facets of a set of data, by simply counting the number of times an activity happens, or a topic is depicted (Fellows and Liu, 2008). After consolidation, this resulted in the identification of

39 rework causes as summarized in Table 1.

Table 1. Summary of rework causes

No.	**Causes of rework in construction projects**
1	Unclear and ambiguous project process management
2	Project scope change after work had been undertaken/completed
3	Revisions, modifications of project function initiated by the owner/ end user
4	Budget compression or increase
5	Schedule acceleration
6	Replacement of materials/equipment during construction
7	Inappropriate/ Contradictory project instructions initiated by managers
8	Poor communication path of project instructions
9	Poor communication/coordination between owner and end-users
10	Delay in providing the site conditions (such as water, electricity etc.) for the contractor
11	Payment of low contract fees or delay in paying contract fees
12	Ambiguous of items from the contract documentation
13	Lack of clear definition of contract documentation for working content
14	Poor contract execution
15	Active rework made by the contractors to improve quality
16	Active rework made by the designers to improve quality
17	Lack of constructability due to separation between design achievements and construction conditions
18	Poor coordination of design team members
19	Design error/omission due to design task too much, time boxing
20	Poor quality of construction technology
21	Use of poor construction materials
22	Un-use of advanced mechanical equipment
23	Poor quality of construction procedure
24	Ineffective use of construction management standard
25	Construction errors caused of incomplete understanding the intent of design
26	Poor communication of construction managers
27	Poor site conditions (such as, water, electricity, telephone, etc.)
28	Changes made by quite difficult construction methods
29	Poor coordination of subcontractor between upstream and downstream
30	Poor communication of construction team members
31	Failure to provide protection to the completed works
32	Poor supervision of admission materials/equipment
33	New request made by the end-users to improve standards during construction
34	New request made by the end-users during final inspection and certification stage

35	Adverse natural conditions（such as hot weather， rain, cold, earthquakes, floods , etc.）
36	Changes in government regulations , laws and policy, etc.
37	Shortage of construction materials/equipment in market
38	Lack of strictly fulfilled for project process management
39	Effect of social and cultural factors

Questionnaire survey

Questionnaire development

A preliminary questionnaire was developed based on the 39 construction rework causes emerging from the content analysis and drafted in simple and clear language to enhance the respondents' ability to exercise sound judgment (Aibinu and Odeyinka, 2006). A pilot study was then conducted involving nine semi-structured interviews to ensure that all the questions were sufficiently stated and to ensure no misunderstandings would arise. The finalized questionnaire contains two parts: the first part is designed to collect general information concerning the respondents, such as work position, education background and working experience; the second part involves rating the 39 rework causes. A 5-item Likert scale was used to measure the importance of each cause.

A total of 425 questionnaires were distributed by email, postal letters and on-site distribution. The regions involved cover various parts of China, including North (Beijing city), East (Shanghai city), West (Chongqing city), and South (Shenzhen and Guangzhou city) China. Over a period of 2 months, 337 questionnaires were returned, comprising 125 emails, 102 by post and 110 questionnaires collected from construction sites. Of these, 60 were discarded due to incomplete or invalid information provided by the respondents. The remaining 277 valid questionnaires are used for analysis, representing a very good response rate of 65.18% (see Table 2 for details) – easily enough for reliable analysis (Moser and Kalton, 1971; Aibinu and Odeyinka, 2006). It is noted that the response rate from construction sites are much higher than the other two methods. This is largely due to the survey assistants being able to explain the questions to the respondents on site and collecting the data *in situ*. Additionally, the sample size is regarded as large enough for factor analysis as the sample size to free parameter ratio is higher than five (Cheung et al., 2009).

Table 2. Summary of response rates

Survey methods	Distributed questionnaires	Returned questionnaires	Valid questionnaires	Response rate (%)
Email	160	125	92	57.5
Postal letter	155	102	79	51.0
On-site survey	110	110	106	96.4
overall	425	337	277	65.2

Figs 1 and 2 provide detailed information concerning the respondents' background. All respondents are from big cities in China, with the majority (around 85%) having more than 10 years' experience in the construction industry. Additionally, 81% hold bachelor or higher degrees. These are considered sufficient to obtain sound judgment from qualified respondents in a perception study of this nature.

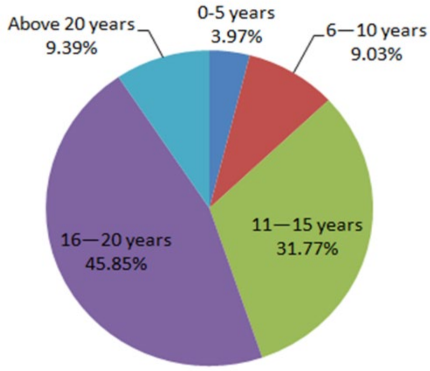

Figure 1. Working experience of respondents

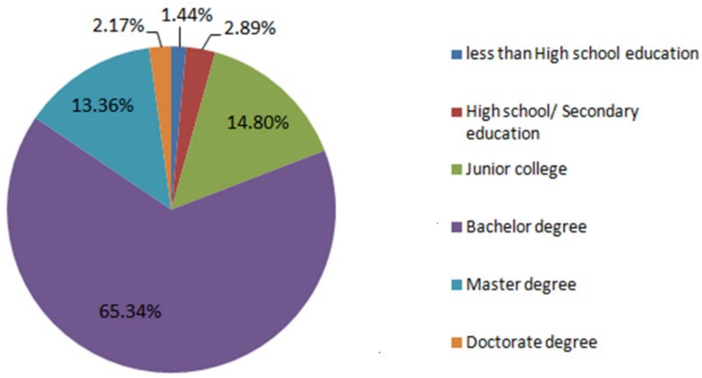

Figure 2. Academic degrees of respondents

Analysis and ranking of rework causes

The Cronbach's coefficient alpha is 0.919 - higher than that 0.8 value needed for the scale reliability to be accepted (Chen, 2010). Table 3 shows the mean and standard deviation of the importance ratings for each cause. If two or more causes have the same mean value, the one with the lower standard deviation is considered to be the more important (Wang and Yuan, 2010).

Table 3: Mean score and ranking of causes of rework

Overall ranking	Causes	Mean	Standard deviatio n
1	Unclear and ambiguous project process management	3.834	1.275
2	Poor quality of construction technologies used	3.794	0.999
3	Use of poor construction materials	3.729	1.095
4	Active reworks made by the contractors to improve quality	3.69	1.092
5	Design error/omission due to design task too much, time boxing	3.643	1.003
6	Poor coordination of design team members	3.632	0.964
7	Change of project scope after work had been undertaken/ completed	3.617	1.049
8	Lack of constructability of design solutions	3.57	1.08
9	Poor communication path of project instructions	3.567	1.139
10	Lack of supervision for admission of materials/equipment	3.495	1.079
11	Poor quality of construction procedure	3.495	1.147
12	Inappropriate/ Contradictory project instructions initiated by managers	3.484	1.115
13	Replacement of materials/equipment during construction	3.44	0.997
14	Acceleration or shortening of the schedule	3.44	1.087
15	Ineffective use of construction management standard	3.415	1.112
16	Revisions, modifications of the project function initiated by the owner/user	3.365	1.06
17	Construction errors caused by incomplete understanding of design intent	3.361	1.158
18	Poor coordination of subcontractor between upstream and downstream	3.357	0.996
19	Poor communication with construction managers	3.307	1.03
20	Obsolete mechanical equipment	3.307	1.092
21	Lack of clear definition of contract documentation for working content	3.249	1.173
22	Compression or increase of the budget	3.209	1.07
23	Failure to provide protection to the completed works	3.181	1.068
24	Poor contract execution	3.137	1.051
25	Lack of strictly fulfilled for project process management	3.13	1.122
26	Adverse natural conditions (e.g. hot weather, rain, cold, earthquakes, etc.）	3.123	1.222
27	Poor communication with construction team members	3.116	1.05
28	Initiative changes made by the designers to improve quality	3.112	1.138
29	Ambiguity of items in the contract documentation	3.076	1.188
30	Poor communication/coordination between owner and end-users	3.022	1.116
31	New request from end-users during final inspection and certification stage	3.011	1.105

32	Delay in providing the site conditions (such as water, electricity etc.) for the contractor	3.004	1.124
33	New requests from end-users to improve standards during construction	2.993	1.06
34	Changes in government regulations , laws and policy, etc.	2.939	1.186
35	Poor site conditions (such as, water, electricity, telephone, etc.)	2.935	1.088
36	Shortage or high price floating of construction materials/equipment	2.928	1.094
37	Change of construction methods	2.91	1.134
38	Payment of low contract fees or delay in paying contract fees	2.892	1.187
39	Effect of social and cultural factors	2.57	1.26

The majority of the causes have mean scores higher than 3.0 (regarded as “important” in the rating scale). An unclear and ambiguous project management process, poor quality of construction technology and use of poor construction materials are the most important, each of which has a mean value over 3.70. An unclear and ambiguous project management process is the most important cause. Some projects rush to start construction with inadequate preparation for project management due to an urgent schedule or arbitrary decision-making involving owner vanity or image issues. This creates much unnecessary rework, which might be avoided by adopting more reasonable project management methods. The quality of construction technology has a vital influence on the quality of construction work. Since the construction industry still has the traditional labor-intensive character in China and makes little use of high technology, the quality of construction work is difficult to control, which often results in considerable rework. Improving construction technology may therefore greatly help in reducing rework. The poor quality of construction materials is also an important cause of rework. As actual cases exposed by the media demonstrate, many jerrybuilt projects in China use poor quality construction materials.

Factor Analysis

Factor analysis is a statistical method used to describe the variability among observed variables in terms of a potentially lower number of unobserved variables, or factors (Chen, 2010). In this paper, a factor analysis is performed to explore the underlying groupings of the 39 causes.

The Kaiser–Mayer–Olkin (KMO) for the 39 variables is 0.868, higher than the 0.5 value needed to be acceptable for factor analysis (He 1998; and Hao et al. (2002), while Bartlett’s test of sphericity is 4552.9 (p=0.000), indicates that the correlation matrix is not an identity matrix (He 1998; Hao et al., 2002) and that the causes are sufficiently intercorrelated (Table 4).

Table 4: Results of the KMO and Bartlett’s tests

Kaiser-Meyer-Olkin measure of sampling adequacy.		0.868
Bartlett's test of sphericity	Approx. Chi-Square	4552.874

	Df	741
	Sig.	.000

The principal component analysis (PCA) generates 11 factors with eigenvalues greater than 1.0, the usual cut-off criterion for determining the number of factors. The 11 factors account for 65.95% of the total variance explained – more than the 60% needed for adequate construct validity (Malhotra 1996; Ghosh and Jintanapakanont, 2004) and the factor loadings for all 39 causes exceed the 0.50 also needed (Kerlinger, 1986). In order to provide a good explanation for each factor, factor rotation is needed (Hao et al., 2002). The final rotated component matrix is presented in Table 5. Each factor can be interpreted and named by combining the meanings of those variables with the highest cross-factor loadings.

Table 5. Factor profile

Details of the factors and causes of reworks	Factor loading	Variance explained
Factor 1: Contractor field management		10.8%
Poor quality of construction technology used	**.813**	
Un-use of advanced mechanical equipment	**.806**	
Poor quality of construction procedure	**.759**	
Ineffective use of construction management standard	**.729**	
Construction errors due to incomplete understanding intent design content	**.588**	
Use of poor construction materials	**.513**	
Poor supervision of admission materials/equipment	**.563**	
Factor 2: External environment		10.3%
Poor site conditions (such as, water, electricity, telephone, etc.)	**.583**	
Changes made by quite difficult construction methods	**.579**	
New request from end-users to improve standards during construction	**.616**	
New request from end-users during final inspection & certification stage	**.583**	
Adverse natural conditions (e.g. extreme weather, earthquakes, floods , etc.)	**.708**	
Changes in government regulations , laws and policy, etc.	**.655**	
Shortage of construction materials/equipment in market	**.636**	
Effect of social and cultural factors	**.685**	
Factor 3: Contract management		7.6%
Payment of low contract fees or delay in paying contract fees	**.680**	
Ambiguous of items from the contract documentation	**.810**	
Lack of clear definition of contract documentation for working content	**.807**	
Poor contract execution	**.618**	

Factor 4：subcontractor management		6.8%
Poor communication of construction managers	**.661**	
Poor coordination of subcontractor between upstream and downstream	**.629**	
Poor communication of construction team members	**.721**	
Failure to provide protection to the completed works	**.688**	
Factor 5: design management		5.3%
Lack of constructability due to separation between design and construction conditions	**.629**	
Poor coordination of design team members	**.747**	
Design error/omission due to design task too much, time boxing	**.784**	
Factor 6: project communication management		4.9%
Inappropriate/ Contradictory project instructions initiated by managers	**.680**	
Poor communication path of project instructions	**.660**	
Factor 7: project plan changes		4.5%
Compression or increase the budget	**.602**	
Accelerate or shorten the schedule	**.770**	
Replacement of materials/equipment during construction	**.560**	
Factor 8: Changes for quality improvement		4.2%
Changes made by the designers to improve quality	**.613**	
Changes made by the contractors to improve quality	**.723**	
Factor 9: client management		3.9%
Poor communication/coordination between owner and end-users	**.558**	
Delay in providing the site conditions (such as water, electricity etc.) for the contractor	**.763**	
Factor 10: project scope management		3.8%
Project scope was changed after work had been undertaken/completed	**.652**	
Revisions, modifications of the project function initiated by the owner/ end user	.784	
Factor 11: project process management		3.7%
Unclear and ambiguous project process management	**.673**	
Lack of strictly fulfilled for project process management	**.553**	

The factors

FACTOR 1: Contractor field management

Factor 1 accounts for 10.83% of the total variance explained. Many studies (e.g. Love et al., 2004; Palaneeswaran et al., 2008; Love et al., 2010) have found poor onsite management to be the main reason for construction rework. This is especially true in the Chinese construction industry, where the majority of work on construction sites is undertaken by migrant farmers. Zhao et al. (2009) show that 87% of migrant farmers have an education level of junior middle school or below, and with little professional knowledge gained before joining construction organizations. This makes field management very challenging for contractors and often results in construction rework. Poor field management of materials and machinery is another major source of onsite rework. In China, many onsite administrative staff responsible for material and equipment management do not strictly control the quality of main construction materials or apply enforced field supervision and inspection. This can result in unsuitable materials and equipment being used.

It would be advisable, therefore, for contractors to increase investment in training construction workers and onsite managers. Training programs such as three-level training (i.e. enterprise-level training, project department training and construction team training) can be used to improve technical and management abilities for onsite operation (Josephson et al. 2002; Huang Guoping 2005). Additionally, a four-level inspection system, such as proposed by Wang (2007) could cover materials and machinery access inspection, safety and maintenance inspection, ex-warehouse inspection and inspection prior to use.

FACTOR 2: External environment

The external environment mainly comprises natural conditions (e.g. extreme weather), end-user requirements, and the social, cultural, legal and market environment. Although it is difficult to control the external environment, its adverse impact on construction rework can still be reduced through suitable measures. For example, rework caused by poor site conditions and change of construction methods can be reduced by proper technical measures, enriched technical means, using construction insurance as an economic measure and establishing an expert consulting system to make full use of external expert knowledge; the impact of requirement changes from end-users can be reduced through effective contract management; while for the social and legal environment, although impossible to control, the impact of changes of policies, laws, regulations and standards can be diminished through effective risk and contract management.

FACTOR 3: Contract management

Wang (2007) considers the contract the basis for cooperation and the essence of construction project management. Since China has long been governed by its planned economy, contract management in construction projects is not taken seriously by many project participants, and many construction organizations and owners even have no independent contract management department or professional contract management staff. Poor contract management can not only cause payment problems in contract execution but also rework due to the ambiguous scope in the contract documentation. Therefore, owners are advised to carefully negotiate the terms and conditions of contracts with contractors and monitor their performance in accordance with the specification and terms of the contract, as well as agreeing and keeping records of any contract changes during the project execution process in order to avoid misunderstandings in the later stages.

FACTOR 4: Subcontractor management

Subcontractor management affects rework as most subcontractors in China obtain contracts under the name of large construction enterprises while not normally possessing the corresponding qualification certificate required by the government (Yue and Jin, 2010). Furthermore, it is difficult to have effective communication between different subcontractors due to the different expertise and knowledge requirements involved. This suggests that the establishment of a subcontractor integrity system, regular coordination meetings and onsite cross checking of subcontractors would provide an effective means of decreasing rework.

FACTOR 5: Design management

Design management is an important factor influencing rework in other countries (e.g. Burati et al., 1992; Love et al., 2002; Hwang et al., 2009). In the construction market of China, owners often require design firms to submit design drawings as early as possible in order to deliver products to market as soon as possible. To meet the submission deadline, many design companies sacrifice the quality of design solutions. Additionally, as design tasks are undertaken by different groups of design professionals, the lack of effective team communication causes design errors or omissions and poor integration of design solutions. Furthermore, the traditional design-bid-build is the dominant delivery system of construction projects in China and largely restricts communications between design and construction parties, leading to a lack of constructability of design solutions. These issues result in poor design quality and cause additional rework in the construction stage. Therefore, establishing a design inspection and supervision system (Jiang 2007; Yan 2009), carrying out constructability analyses of design solutions (Love et al., 1998; Love et al., 2004) and using integrated procurement systems such as design-build and construction management (Xia et al., 2009) is likely to improve design management and hence reduce rework.

FACTOR 6: Project communication management

Project communication management provides a significant means of exchanging information between project managers and other stakeholders and it is especially important for the contractor to effectively coordinate with the owner to avoid misunderstandings or conflicts occurring during the process stage of a project. The organizational structures of the majority of Chinese construction companies have a straight line or functional form, which is not effective for internal and external communication. A matrix organizational structure would be more suitable. In addition, although information communication technology (ICT) is widely adopted by major international contractors to improve their project communication management capability, it is seldom used by

Chinese contractors in their project management practice. ICT is therefore likely to enhance project communication efficiency and reduce rework caused by communication mistakes. Similarly, regularly meetings should be beneficial for information sharing and updating, to further reduce the possibility of rework.

FACTOR 7: Project plan changes

In construction projects, schedule adjustment and investment changes often occur because of poor owner process management. Although it is impossible to avoid plan changes completely, establishing a "whole-process consultation mechanism" to combine economic and organizational measures can reduce unnecessary changes, improve the efficiency of process management and help in effective change management (Ren and Zhang 2005). Additionally, contractors could provide professional suggestions to owners to mitigate the risk of adverse changes and adopt strategic countermeasures to manage the changes that occur during the construction process.

FACTOR 8: Active rework for quality improvement

In contrast with previous studies, the findings from this study show that rework does not always have a negative effect. Designers and contractors may rework actively for cost and time saving, quality improvement, and meeting the project owner changes. Given that early rework lessens the loss to the project, it follows that the decision to rework should be made as early as possible. Value management tools and rework reward mechanisms can be applied to identify the appropriate rework needed.

FACTOR 9: Owner capability

Project success generally depends on owner capability (Kerzner 1995; Xia and Chan 2010); owner effectiveness in defining and formulating the project (Cleland, 1994); and owner financial status, characteristics, management competency and construction experience (Lim and Ling (2002). Chinese project owner management capabilities vary greatly across different types of projects and organization structures, etc. For example, as most of civil projects in China are initiated by the government and owner responsibilities are undertaken by a temporary organization established by the government, the management capabilities of project owners in this type of temporary organization tends to be quite low. Therefore, it is helpful to transfer owner experience and knowledge obtained from one project to another efficiently in order to avoid the repetition of mistakes causing rework.

FACTOR 10: Project scope management

Project scope is the significant guarantee for achieving project objectives (Ren and Zhang, 2005). However, although the Chinese construction industry has experienced a rapid growth over the past 30 years, it is still at an immature stage and the importance of scope and strategic management in the early project stages has not been fully recognized, with many project owners overly focusing on the construction stages and early completion of the project. A lack of clear project scope in the early stages can result in frequent revisions and modifications of project functions during the design and construction stages. Enhancing owner scope management capacity and establishing an "early-stage consultation mechanism" (Zhang, 2004) and "early-stage participation mechanism" (Zhu, 2008) should assist owners in clearly specifying project objectives and performance specifications and reducing changes in project scope so as to decrease rework effectively.

FACTOR 11: Project process management

The rapid growth Chinese construction industry has also caused a shortage of qualified project managers in recent years (National Bureau of Statistics of China, 2012). As a result, some project managers are either unfamiliar with, or unwilling to follow, good project management practice - such as violating the basic program of engineering construction and inappropriately shortening the construction period, making "three-way projects" (projects are surveyed, designed and constructed at the same time) a common phenomenon. These "three-way projects" frequently lead to continuous changes in the construction phase, causing additional rework. In many cases, the "three-way projects" are due to regulation violations from owners and lack of supervision from administrative departments and suitable "three way measures" (contractor process management system, owner reporting system, government notice and three-way-projects shut-down system) are needed to overcome these problems.

Conclusions

Construction project rework is a major problem in construction and engineering projects worldwide and, with the direct rework cost alone ranging from 5 to 20% of contract value, has significant implications on project success. Despite a number of studies, little is known of the causes of rework in developing countries such as China, a country with the largest construction industry in the world and where most construction companies are have serious rework problems. This paper rectifies the situation with a survey of 277 Chinese construction industry practitioners and factor analysis to identify 11 main groups of rework factors comprising design management, communication management, field management, project scope management, project process management, active reworks, project plan changes, subcontractor management, contract management, owner capability and external environment.

As the majority of rework causes identified in this study confirm those found in previous work, the findings from this study consolidate the existing knowledge with new evidence from China. New causes, such contract management, active reworks and scope management are also identified, which helps expand existing knowledge for the global construction community.

Specific attention should also be paid to the *active rework*, which implies that reworks can also bring positive effects to construction projects.

The research findings provide some practical implications. Effective rework management requires the close collaboration of all stakeholders involved in different project stages (e.g. owner, designer, subcontractor, supervisor, administrative department) and the adoption of both management and technical measures. For example, owners should provide clear performance specifications at the request for proposals in order to reduce changes in project scope that lead to rework in the design and construction stages. If owners are unable to define project scope with their own resources, the aid of external consultants may be required. Design consultants should improve the constructability of design work through effective communication both within different groups of design professionals and between owners and contractors. Value engineering could be also adopted to enhance quality of design. In terms of contractors, in addition to field management and project process management, improved project communications and subcontractor management should also help to reduce rework.

Finally, further research is needed to establish a comprehensive rework management system that involves different stakeholders as well as different organizational and technological measures in the different project stages. This should be of great help in reducing and preventing rework and improve the productivity of the construction industry in China and beyond.

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