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FIELD DIAGNOSIS OF CAUSES AND EFFECTS OF REWORK IN HIGHER EDUCATION RESIDENTIAL FACILITIES

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ABSTRACT

Purpose: The aim of this paper is to examine the causes and effect of rework occurring in construction projects so that effective containment and reduction strategies can be developed. Methodology: Case studies were conducted on purposive selected construction projects based in Cape Town to establish the causes and effect of rework. Specifically, qualitative data was collected by means of observation of physical works, semi-structured interviews with relevant parties directly involved into site operations including the contractor’s management team, consultants and subcontractors, and site instruction record documents were analysed. Findings: It was revealed that changes initiated by the client and the design team due to errors and omissions, poor coordination and integration among the design team were the major contributing factors to rework. Moreover, constructability problems, lack of skills and emphasis on time and cost aggravated the occurrence of rework on site. It was also established that rework has both direct and indirect consequences such as cost for redesign, cost of demolition, litigation cost, poor morale, demotivation and loss of market share in construction projects. Limitations: Only two multiple storey educational facilities were analysed and as a result the reported findings cannot be generalized. In addition, causal histories for identified rework events tended to be grounded in the views of the contractors and as result there is a potential for bias to exist. However, the findings reported are akin to what the normative literature has reported. Value: The study suggests that design and construction firms must develop organisational measurement systems to track rework. It is only through its determining its frequency and cost can effective strategies for its containment and reduction can be identified.

KEYWORDS
Causes, construction, errors, omissions, rework.

INTRODUCTION

The construction industry has been heavily criticised for its performance and productivity with cost and schedule overruns becoming a norm [1]. A significant factor that has been identified as contributing to this setback is rework. It is a non-value adding activity and can be defined as the “unnecessary effort of redoing an activity that was inaccurately done the first time” [2]. Rework can be as high as 12.4% of the total project cost [3] and can contribute to increase total project costs by 10% [4]. Such costs could however, be substantially higher as they did not account for schedule delays, litigation costs and other intangible costs of
poor quality \cite{4, 5, 6}. Indirect cost of rework could be as much as six times the cost of rectification \cite{2}. While rework has been identified as a problematic issue in projects, there remains limited knowledge about its causes and effects in construction projects. With this in mind, this paper aims to determine the causes and effect of rework that occur during construction so that effective containment and reduction strategies can be developed.

**SOURCES OF REWORK**

Rework arises from various sources such as errors (slips, lapses, mistakes and omissions) and changes. Errors are unintentional deviations from correct and acceptable practice, and therefore, are avoidable \cite{7}. However, omissions are deliberate acts and are essentially “failures to follow due procedure when undertaking a task” \cite{8}. Design related rework in the form of change orders is the major source of rework in construction projects \cite{9, 10, 11, 12, 13}. In fact, a change is essentially a directed action that alters current established requirements. While changes can be readily accounted for in terms of direct impact, errors on the other hand, remain a hidden and unknown nemesis within projects \cite{11}.

Errors

In a study of nine large industrial construction projects, it was found that rework originating from the design error contributed an average of 79% of total rework cost \cite{14}. Errors are often not immediately identifiable and only become evident after a period of incubation in the system \cite{15, 16}. The extent of rework required depends on how long the error has remained unnoticed. For instance, a dimensional error or spatial conflict contained within design documentation may not arise until the project is being physically constructed on-site \cite{16, 17, 18}.

Omission errors arise when the mental process of action control is subjected to strain or distraction \cite{19}. In fact, omission errors are a result of pathogens within a system that translate into error provoking conditions within the firm and project. Examples include time pressure, understaffing, fatigue and inexperience \cite{20}. Unfortunately, latent conditions contribute to unworkable relationships and procedures as well as design and construction deficiencies consequently contribute to rework \cite{20}.

Failure to undertake procedural tasks during the design process \cite{21, 22, 23} and continual design reuse \cite{24} are leitmotifs that emerge as practices contributing to omission errors. The work practices implemented by organisations can provoke similar errors, regardless of the skills and experiences of the people involved in a project. For example, low design fees contribute to design checks, reviews and verifications are omitted by architects and engineers \cite{25}.

**CAUSES OF REWORK**

The causes of rework can be categorised into different groups such as client-related, design-related and contractor-related, and sub-contractor-related \cite{26}. A brief overview of rework causes are presented hereinafter.

**Client-related factors**

Clients and their project team members must communicate and work together in harmony if projects are to be delivered on or ahead of time \cite{27}. Client-related factors contributing to rework include lack of experience and knowledge of design and construction process; lack of funding allocated for site investigation, lack of involvement in the project, inadequate briefing, poor communication with design consultants; and inadequacies in contract documentation \cite{28}. 

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Design-related factors
Lack of design coordination and integration between project team members can lead to design deficiencies and exacerbate the causes of rework. Source of design-related rework is attributable to communication problems [12]. Ineffective use of information technology in managing and communicating information aggravates the amount of rework that occurs in a project [29]. A study to quantify the causes and cost of rework on construction of residential homes and industrial warehouses revealed that poor coordination and integration between design team members hindered the flow of information among them [30]. It was revealed that engineers used CAD technologies and the architects used manual systems to document their designs [30]. As a result, some drawings were issued with dimensional errors and missing information [30]. Indeed, reducing design fees can result in inadequate contract documentation being produced, which often results in rework, claims and contractual disputes [31].

Contractor-related factors
The inability of many supervisors to plan work, communicate with workers, and direct activities adequately contributes to rework [32]. Site management team and subcontractors project success is dependent upon the effectiveness of the main contractor's construction planning efforts [33, 27, 34, 35]. It has been identified that projects without a quality system in place can experience a 10% cost increase due to rework. Other factors identified contributing to rework includes [36]:

- Setting-out errors as a result of misreading dimensions on the working drawings [12].
- Staff turnover and reallocation to other projects [13]; for instance increased defects and poor workmanship may arise as a result of excessive workload, multitasking and unwarranted pressures for early completion; and
- Failure to provide protection to works [10]. For example, failure to provide protection during painting work whereby paint splashes on floor finishes and sanitary fittings.
- Failure to protect certain parts of a building during alteration works.

In the case of subcontractors specific factors contributing to rework included: inadequate supervision, damage to other trade's work due to carelessness, low skill level of construction artisans and labour; and poor use or choice of materials [13, 37, 38].

EFFECTS OF REWORK
Rework specifically in the form of changes can have an effect on the aesthetics and functional aspects of the building, the scope as well as the nature of work, and its operational aspects [11]. It can also adversely affect an individual, organization and project's performance and productivity [39, 2]. When an individual is subjected to having to work longer due to errors, changes or omissions, fatigue and stress may emerge, which can increase the likelihood of further rework occurring [40,41]. At the organisation level, it has been identified reduced profit, diminished professional image, inter-organisational conflict, loss of future work and poor morale as indirect effects of rework [42]. At the project level, work inactivity such as waiting time, idle time and travelling time and end-user dissatisfaction were identified as indirect consequences of rework.

METHODOLOGY
There has been limited research undertaken in South Africa about the causal nature of rework in construction projects. As a result an exploratory research approach was adopted to determine the causes and effects of rework.

Purposive sampling method was used to select two construction projects based in Cape Town. These projects were selected on pragmatic considerations, namely their availability. Purposive sampling consists of handpicking purportedly typical or interesting cases. Purposive sampling is tagged as theoretical sampling. It is a useful sampling method consisting of receiving information from a sample of the population that one thinks knows most about the subject matter. In fact, there is no ideal number of cases that should be undertaken. Semi structured interviews with relevant parties including the site management team, consultants and subcontractors. Observations of physical building, and site documentary sources such as site instructions, revised working drawings and progress reports. A framework of questions for the interview was designed to collect information relating to the causes of rework on site, the influence of human resources capability and quality management practice on the occurrence of rework. Other information included the effect of rework on the project’s critical path, their companies and overall project performance. Respondents were first informed of the focus of the interview prior to meeting. This assisted the respondents to prepare adequately for the interview in advance. Each interview was tape-recorded and subsequently transcribed. Also, direct observations were made by the researcher and notes were taken with the aid of a notebook and pen to derive data.

FINDINGS

Case description – project a

Project A consisted of a two-storey university residential apartment situated in the suburb of Bellville in Cape Town. The total floor area is 3800 m². It contained a total of 200-beds, a communal kitchen, TV room and an open court yard with a landscaped area in the middle. The contract value for the development was R30 million with a contract period of 14 months. The project was procured using a competitive tender with bill of quantities and working drawings, with the client employing an architect as the project manager to act as their development representative. The contractor’s contract manager and quantity surveyor were interviewed on this project. The interviews were conducted on site in the contract manager’s office and quantity surveyor’s office respectively, and lasted 60 minutes.

Causes of rework

Changes initiated by parties involved

According to the contract’s manager about 40% of the changes initiated on site constituted rework. An example of a change requested from the architect stated “a decision has been made regarding the type of pipe to be installed; it must be either HDPE or PVC pipe”. The contract manager mentioned that during that stage they had already done the surface bed preparation to receive the concrete bed when this decision was taken as a result the plumber had to excavate through the sub-base in order to lay the pipe and this basically affected the plumber and civil work contractor.

Design errors and omissions
The contract manager stated that design errors and omissions had been made by the design team. The contract manager attributed the errors and omissions to lack of information flow between the architect and structural engineer. The contract manager provided an example where the engineer’s drawing layout indicated columns needed to be off-shutter finished whereas there the architect’s drawings provided no indication about the required finish. The contractor casted columns according to engineer’s drawing, however, during a site visit architect realized that columns exposed to the walk way area were not off-shutter finished. As a result, the architect issued an instruction for those columns to be skimmed and plastered. The contract manager also stated that, in some case sleeves were installed in the slab using the structural drawing, subsequent to that, the contractor received drawings from the electrical engineer which indicated that sleeves already installed must be removed.

**Construction error**

According to the contract manager some changes were initiated by the contractor which constituted rework. These changes were initiated as result of construction error. The contract manager stated that during the erection of the perimeter facing brick wall on one side of the building it was realized that the cavity between the rough and facing brickwork was 10mm instead of 50mm. The contract manager admitted that it was due to setting out error on the part of the main contractor’s supervisor.

**Effect of rework**

The contract manager indicated that the architect was dissatisfied when the cavity between the facing and rough brickwork, as it was 10mm instead of 50mm. A summary of the causes and effect of rework experienced from the case study for project A can be seen in figure 1. The contract manager pointed out that the cost associated with redoing the facing brick wall to ensure that the cavity was 50mm was born by the contractor. However, the quantity surveyor revealed that there are no mechanisms in place in capturing the rework cost on site. According to the contract manager the rework that occurred on-site had adversely influenced the morale of subcontractors and labourers. For example, the plumber’s resources had been stretched due to the amount of rework that they had incurred.

![Diagram](attachment:diagram.png)
The contact manager stated that overtime and disruption were impacting the plumber and other trades. As the roof was being installed, it was revealed that, the electrical consultant, for example, did not design the conduit root for the fire evacuation. As a result the architect had to employ another organization to do the design work immediately, which resulted in the electrical contractor to work over a weekend at considerable extra cost to the project.

Case description – project B
Project B consisted of a 7-storey educational facility situated in Observatory a suburb of Cape Town. The total floor area was 6000 m². It contained 887 units with en-suite bathroom, 91-kitchens, two-court yards with a central communal area and underground parking are among the facilities incorporated in this development. The project was a competitive tender with bill of quantities, the contract value for the development was R286.6 million with a contract period of 22 months. A project manager was employed by the client to act as their representative. The following people were interviewed, contract manager, planner, junior site manager, quantity surveyor, bricklayer foreman and the junior architect from the design firm. The interviews ranged from 15 to 50 minutes.

Causes of rework

Changes initiated by parties involved
According to the contract manager and planner changes were initiated by the design team. The planner stated that one such example was made by the architect who specified changes to window sizes in a section on the first floor. However, all the windows were in place when the revised drawings were received. An instruction was issued by the architect to remove all windows and replace them with new ones in accordance with the new revision. At the time the research was being conducted, the contract manager indicated that the principal agent had issued their 16th revised drawings for the services drawing due to major changes in the services duct.

Design errors
Interviewees stated that design errors and omissions on the part of the mechanical engineer resulted in clashes and changes in services and as a result some portions of the brick wall were removed to accommodate the service ducts.

Construction errors
Interviewees stated that there had been construction errors caused by the contractor and subcontract which required rework. The junior site manager stated that some columns were demolished as a result of honeycombing after casting. The junior site manager stated that the concreters were not sure as to how to vibrate columns of sizes 1000x300mm since they were used to casting columns of sizes of 300 x 300mm. Furthermore, it was stated that two more columns had to be demolished due to setting out error as some columns were 25mm out of place. Inexperience on the part of the leading hand, and lack of coordination between the leading hand and surveyor were identified as contributing factors in this instance.
Effect of rework

According to the contractor's quantity surveyor, there is no mechanism in place for tracking rework cost. Figure 2 illustrates the causes and effect of rework experienced in the case study for project B. The planner stated that some members of the design team were dissatisfied in the beginning as the drawings were not strictly followed. The plumbing consultant was particularly dissatisfied with the work of the plumbing subcontractor. For instance, the gradient for the surface water drainage in one of the court yards was incorrect due to setting out error on the part of the subcontractor.

The contractor was also dissatisfied due to many changes on the part of the design team. The site agent stated that morale of workers for certain trades especially bricklayers, plumbers and electricians were affected by rework. Contact manager further stressed that sometimes rework lead to dilution of supervision on site (thus supervisors become confused when there is any incident of rework because they have to re-plan the work). In terms of litigation the planner suggested that a contractual dispute was materialising as a result of rework with regard to the roof construction as a number of design deficiencies had occurred.

CONCLUSION

No significant differences in the causes of rework between project A and project B. In both projects it was found that rework was attributable to changes initiated by the design team and design errors originating from poor detailing. Omissions due to poor coordination and integration amongst design team members and errors during the construction stage were also identified. Lack of experience with various building types and construction techniques were apparent in project B. In this instance, the contractor had a vast amount of experience with constructing industrialised buildings comparatively to high rise buildings. Training and knowledge are immediate issues that contractors need to grapple with in order to reduce on-
site rework. Unless effort is made to improve skills and knowledge, reputation, delays and disruption and loss of profit will become products of rework that arises on-site.

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REFERENCES


